THE SOIL SCIENCE SOCIETY OF FLORIDA

●

PROCEEDINGS
VOLUME V-A
1943

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Interim Meeting of the Society
Belle Glade and Clewiston
March 17 and 18, 1943

Reclamation and Soil Conservation Problems of the Florida Everglades — A Continuation Discussion

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1943

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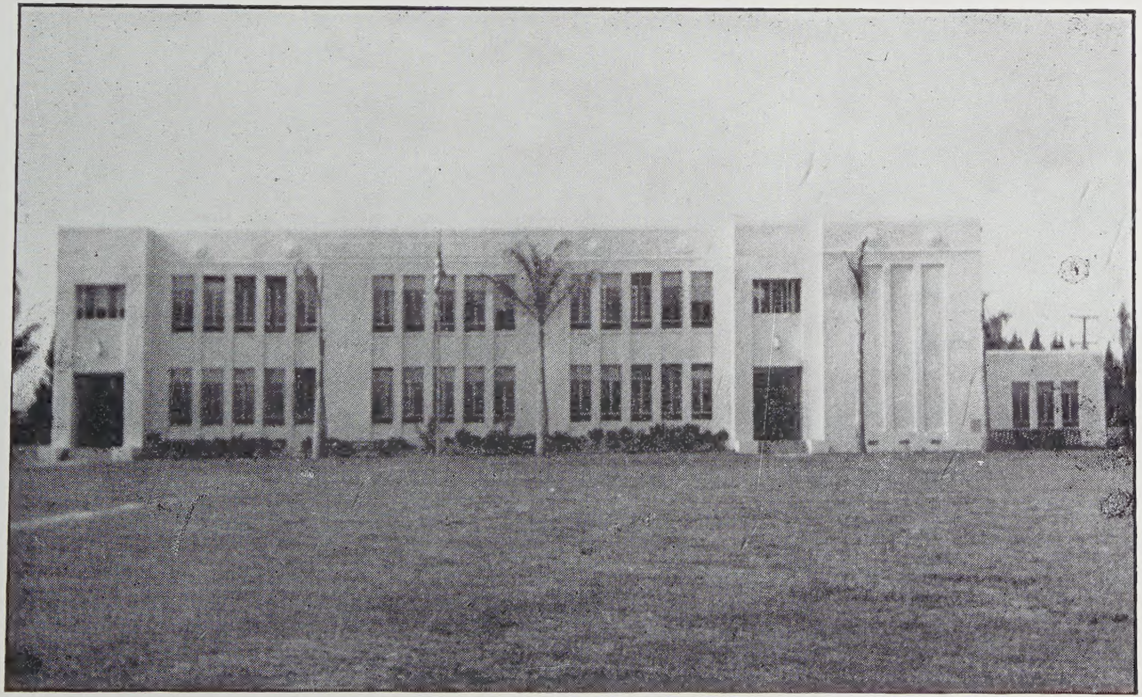

BELLE GLADE HIGH SCHOOL
(1943)

It is especially fitting that public meetings for the discussion of vital questions of this nature be held in public schools and the more advanced students be given every opportunity and encouragement to attend since the near future will find the problems of soil and water conservation and all they stand for fully in their hands.

ACKNOWLEDGMENTS

We are deeply indebted to the citizens of Belle Glade, of Palm Beach County and of all South Florida whose interest in the development and welfare of the Everglades made a second meeting for the discussion of its many problems an eminently successful one.

We are also greatly indebted to the courtesy of Principal Frank Hobson and to Palm Beach County Superintendent of Public Schools, Dr. John I. Leonard, through whom the excellent facilities of Belle Glade's modern high school were made available for the morning and afternoon sessions of March 17th.

It is a pleasure, furthermore, to acknowledge our gratitude to the many workers, members of the Society and others, who took an active part in this program and especially to that of the Honorable Nathan Mayo, Florida's eminent Commissioner of Agriculture, whose far-sighted interest in this connection the Executive Committee have undertaken to record in a more tangible form by dedicating this volume to him.

Finally, there is the perennial but highly important vote of thanks due those who have given us sustaining memberships during the year and, by these contributions, made possible the publication of these important papers and discussions in the form of Volume V-A of the Proceedings of the Society.

List of Sustaining Members

(1943)

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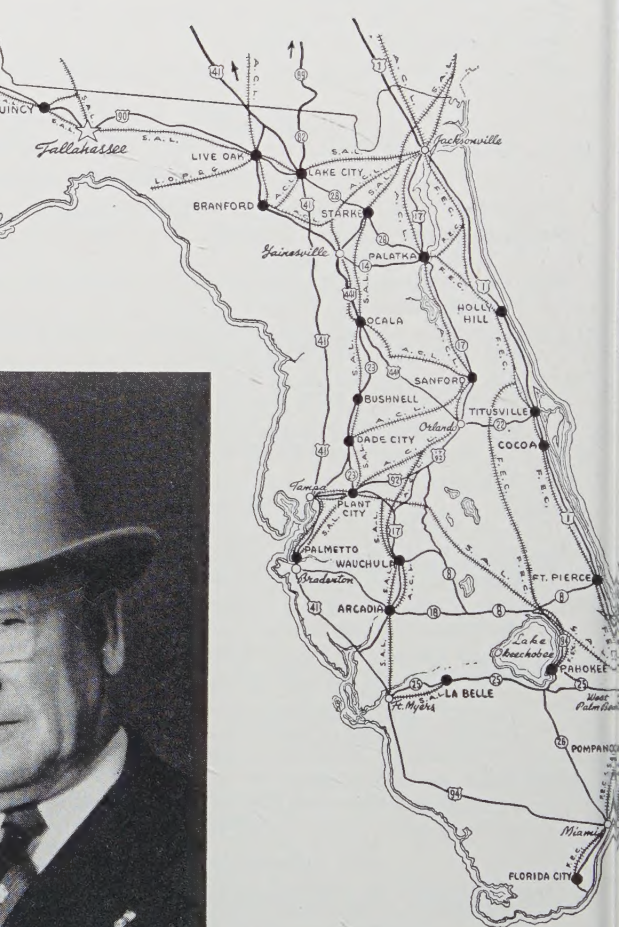


HONORABLE NATHAN MAYO
Commissioner of Agriculture
Since 1923

DEDICATION

THE HONORABLE NATHAN MAYO
COMMISSIONER OF AGRICULTURE

It would be difficult to include within the confines of a statement so brief the many and varied ways in which the people of Florida are indebted to Mr. Mayo for the highly efficient manner in which he has developed the State Department of Agriculture and the thoroughly business-like way in which the manifold divisions of that department are operated at the present time.

When Mr. Mayo became Commissioner of Agriculture on November 1, 1923, there were a total of nineteen employees. The responsibilities of the Department now have been developed to such an extent as to require a year-round staff of 175 with the peak employment reaching as high as 400 for the handling of seasonal work. This largely has been brought about by the organization of an orderly Inspection Service which includes fertilizers, gasoline, citrus and other materials and products of direct interest and concern to agriculture. A characteristic feature in one of these services that typifies the conduct of the whole work of the Department is a traveling gasoline laboratory. This is the first of its kind in any state and is proving so uniquely effective in handling the problems of this particular branch of the work that it is being used as a model by other states!

One of the earliest interests of the State Department, under Mr. Mayo's leadership was the agricultural development of the Everglades. In 1923 there were practically no improved roads through this great area and communications by land were so exceedingly difficult that a considerable part of the travel and transportation up to that time had been accomplished by water. By 1926 limited stretches of improved highways had been built. The Clewiston-Belle Glade highway was opened for travel in 1929 and that between Belle Glade and Pahokee in 1927. So great was the Commissioner's faith in the productivity of Everglades land that by 1932 construction work on State Farm No. 2 was begun on the Pahokee Road about 2 miles north of Belle Glade. Since that time hundreds of tons of food in the form of rice, sugar, molasses, dried beans, onions, potatoes, citrus and canned beans, tomatoes and peas have been produced on this farm through the use of prison labor all with a very great saving to the people of the State. As the Everglades Farm has come to prove the wisdom of its founder's judgment there has gradually developed the plan to allot to it the responsibility for the production of food crops for all State Institutions, while the great farm at Raiford in North Florida will be devoted more and more to extensive types of operations such as pasture and livestock. This has meant a progressive expansion of the Everglades operation until presently it is expected to include at least 3,000 acres.

The long-time interest of the Commissioner in the adaptability of the Everglades to the culture of such promising crops as ramie has been emphasized by the planting of a considerable acreage of this fiber plant on State Farm No. 2, north of Belle Glade, during the past few years as a source of cuttings against the time they will be needed for commer-

cial plantings when a satisfactory machine has been developed for the decortication of the plant on an adequate scale of operation.

Incidentally, Florida was the first state to provide funds with which to deliberately advertise its great resources and opportunities by way of attracting tourists and inducing home-seekers to settle here. That this activity has been carried on by the Department of Agriculture for the past twenty years in a most effective manner is attested by the fact that during the last decade she has led all other states in the rate at which her population increased.

Another of Mr. Mayo's outstanding projects has been the development of a unique system of Farm Markets in the principal agricultural centers of the State to cooperate with growers in the sale of their livestock, fruit, tobacco, and vegetables of various types, according to the specialties of the region in which each is located. Twenty-eight such markets have been established in various parts of the State with an additional one under consideration for vegetable crops at Ft. Myers.

While it would be difficult to find a better evidence of Mr. Mayo's personal concern over the welfare of the small farmer than the State-wide system of cooperative markets that has been developed by his Department, its equal, at least, may be found in the keen interest he is now showing towards the organization of a comprehensive system of soil testing such as Florida has needed for some time. Such a service to the growers of the State can well be developed as a sound foundation and an efficient background for the operation of the markets which have been organized for them.

In dedicating this volume, the second report of the Soil Science Society of Florida to deal exclusively with the soil and water conservation problems of the Everglades to the Commissioner of Agriculture we would be remiss, indeed, if the part Mr. Mayo played in the success of these meetings were not properly acknowledged. No one recognizes more clearly than he does the serious nature of our conservation problems in the Everglades. No one desires more earnestly than he to do something about them. The fact that he found time in an ever busy schedule to attend and take an active part in both of these special meetings of the Society, the first in West Palm Beach in April, 1942, is a considerable testimony to his interest. However, it was the dynamic nature of his participation in the Belle Glade meeting, as recorded in the present volume, which brought the whole effort at centralizing all responsibilities involving the Everglades in the hands of the Board of Commissioners of the Everglades Drainage District to a head. This action culminated in the meeting, which he recommended, of a representative group from South Florida with the Governor and his Cabinet in Tallahassee on April 14, 1943. Susequent trends indicate that decisions arrived at during that meeting are marking a new era in the handling of Everglades affairs. There can be little doubt in the minds of those who have closely followed these events of our indebtedness to Commissioner Mayo for the guidance he has given these trends. Neither can there be any doubt in those minds as to his willingness to support to the limit any future program that has the welfare of the soil and water resources of the Everglades truly at heart, especially since the people who live there and work these soils are so utterly dependent upon an improved handling of these resources.

GUEST SPEAKER

John H. Baker has had a hobby interest in observing wildlife since he was a small boy. After some seventeen years of business experience in manufacturing, foreign trade and investments, as well as two years as an Army airplane pilot in World War I, he has devoted his time for the past ten years to the affairs of the National Audubon Society, of which he became Chairman of the Board in 1933 and Executive Director in 1934.

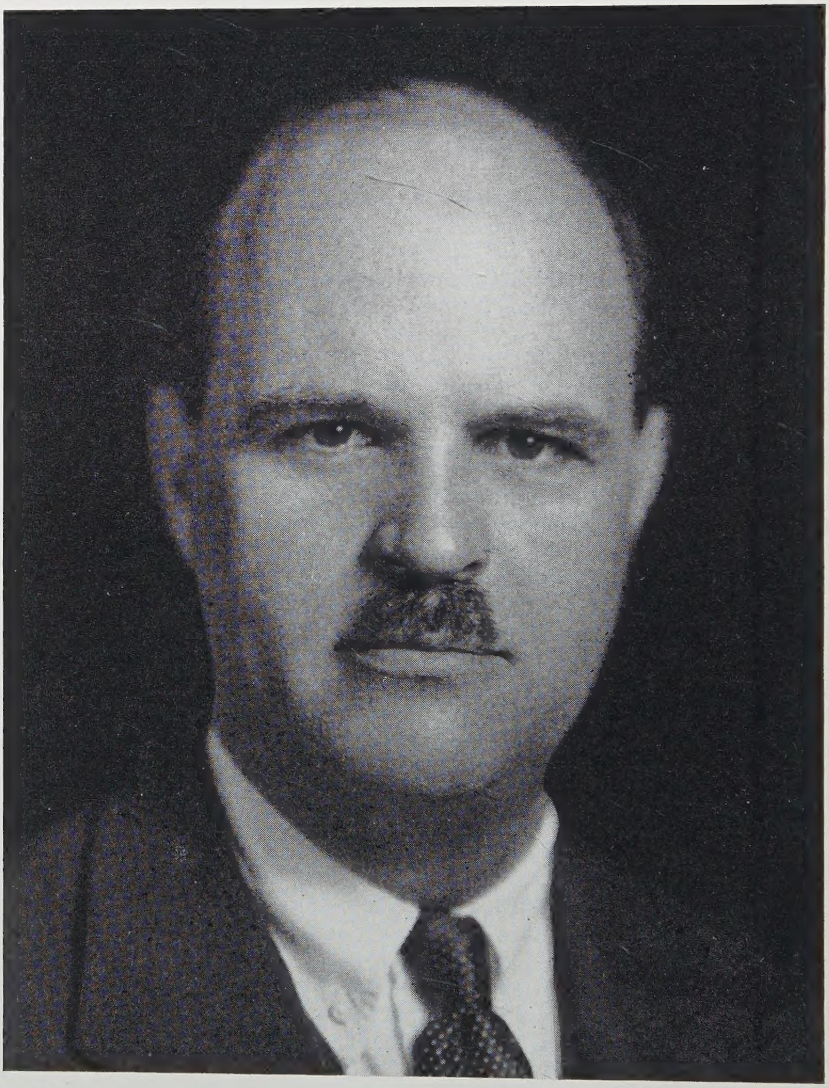
In supervising and directing the nationwide educational, research and sanctuary activities of the National Audubon Society, Mr. Baker has become well acquainted with wildlife conservation problems on this content. Because of considerable concentration of the Society's sanctuary work in Florida, he has become especially familiar with the southern portion of this State, more particularly from the Kissimmee Prairie and the shores of Okeechobee south through the Glades to the Ten Thousand Islands, Cape Sable and Florida Bay.

He is a member of the Century Association (New York City) and of numerous scientific and ornithological societies, including American Ornithologists Union, Cooper Ornithological Club, Wilson Ornithological Club, Wildlife Society, Linnaean Society of New York, American Association for the Advancement of Science and American Mammalogists Society.

He is also a member of the Soil Science Society of Florida and of the Advisory Committee appointed by the Society at the request of the Board of Commissioners of Everglades Drainage District to advise on the present drainage system in relation to water control requirements of the district. The appointment is particularly appropriate in view of the fact Mr. Baker has been active for a number of years in promoting the establishment of the proposed Everglades National Park and of wildlife refuges in southern Florida.

After having heard Mr. Baker present one of his magic word pictures of Florida landscapes, overhung with pluming clouds, showered with golden sunsets and animated by great flights of lovely birds, scarcely anyone would expect that at the next moment he might engage in an equally animated discussion of the production of purebred Aberdeen Angus cattle on his farm in Dutchess County, New York. However, this is the case and it well explains the breadth of viewpoint which he brings into the consideration of soil and water conservation and the protection of wildlife, especially at such points as requisite measures for these purposes find logical contact with practical agricultural activities and development.

The Society's wardens now patrol in the United States some 3,000,000 acres of land and water to protect wildlife, especially the birds in their great nesting, roosting and feeding concentrations, of which there are many outstanding examples in southern Florida.



JOHN H. BAKER

WILDLIFE PRESERVATION IN THE GLADES [1]

John H. Baker [2]

Ladies and Gentlemen of the Soil Science Society of Florida and of the Clewiston Kiwanis Club:

I appreciate very much indeed the opportunity to be here with you this evening. The warmth of your reception makes me feel very much at home.

Through frequent visits to South Florida during the past ten years, I have come to have great appreciation for your country and great affection for your people. My excuse, therefore, for venturing to speak to you this evening about the wildlife of South Florida and, more particularly perhaps, of the current efforts of the National Audubon Society to further its protection, is that I have on many occasions traversed the Glades, the southwest coast and Florida Bay, not only on foot, in boat and by car, but by plane, glades buggy and airboat. Our Society maintains in South Florida three full time Audubon wardens with necessary equipment, and three additional seasonal wardens. Naturally, we are vitally interested in plans for the wise use of the Glades.

It is quite usual for people I meet here and there to greet me with some such question as, "How are the birds?" And very likely quite a few in this audience associate the National Audubon Society primarily, if not wholly, with the protection of birds. Yet, for a good many years now, our scope of interest and effort has been far broader and, indeed, includes not only the promotion of increased public appreciation of the values of wildlife and the need of its conservation, but also of soil, water and plants. These natural resources are all interdependent, and no intelligent plan of land use can, in our opinion, be worked out unless all of these factors are duly taken into account in proper relation.

There have been, through the years, a good many societies for the preservation of this or that specialty, and I wonder if that has not to a considerable degree been a cause of much delay in acceptance by the public of the importance of conservation. As a theoretical illustration, one might say it has availed us little if The Society for the Preservation of the Cardinal or Red Bird has been warring with The Society for the Preservation of Sunflower Seeds!

All animals, even as you and I, are dependent upon food, water and cover, and the adequate provision of these depends upon proper conservation and natural balance of soil, water, plants and wildlife. Today, more than ever, with better trains, better planes, better refrigeration, better guns and ammunition, with roads cutting through the heart of what until recently were wilderness areas, wildlife needs for its reasonable preservation the establishment of far more refuges and sanctuaries in which it may live undisturbed by man.

One of the fundamental freedoms of democracy is the right to exercise individual initiative. That, naturally, leads to much exploitation

[1] Accompanied by a wildlife movie, in color.

[2] Executive Director, National Audubon Society, since 1934.

of natural resources. Yet it is one of the satisfactions of democracy that, as the resulting damage becomes apparent, the majority of people in an affected community—be it township, county, state or nation—usually demand the application of conservation practices. The Audubon Societies conceive it to be their duty to endeavor, through the dissemination of information and other educational methods, to reduce the time lag and hasten the moment when the public imagination will be captured by the conservation rather than the exploitation concept.

People sometimes ask, with regard to birds and other wildlife, "What good are they?" I like to reply, "What good is a sunset, or a snow-capped range of mountain peaks? Is there no other measure of value than at the cash register or box office? Are there no other values of wildlife than as meat or targets?" A moment's thought brings realization that not only are there tremendous esthetic values from man's recreational standpoint, but the economic importance is basic to man's material benefit on this earth. All birds and other wildlife have their particular role to play in naturally controlling other animals and plants. In the absence of such natural action and counter-action, many forms of animals and plants tend to become "weeds" or pests.

The principal activities of the National Audubon Society are educational in character. Over 6,000,000 American and Canadian children in schools and youth groups have been members of Audubon Junior Clubs. Probably most of these are still alive and their combined influence in stimulation of public appreciation of nature must now be considerable. Through our illustrated Audubon Magazine and the publication of many special leaflets; through lectures by members of our staff; through the showing of such colored motion pictures of birds and other wild life as you are to see here this evening; through the organization of Audubon wildlife tours by station-wagon and boat, as carried on in recent years in the Okeechobee region of Florida, in Virginia, in South Carolina and California; through the operation of a summer camp for teachers and youth leaders in Maine; and more recently through the establishment of the Audubon Nature Center in Greenwich, Connecticut, where an active nature educational and research program is currently in process of development, the Society spreads its message far and wide throughout the nation.

The work of the Audubon wardens is primarily of educational character. These men are not instructed to make a record of arrests and convictions for law violations, although they are fully empowered by the Federal and State governments to enforce those laws and it is their duty to do so. But their primary function is, through talking with the people living in and visiting the areas they patrol, to bring about gradually a greater appreciation of the value of birds and other wildlife alive rather than dead; to induce gradually a change in basic attitude toward these anmials; to demonstrate that there is more dollar and cents value, let alone other values, in these animals if alive than if used merely for targets or for food.

Before showing you a reel of pictures of the colorful and beautiful water birds that congregate annually to nest in great rookeries in your South Florida country and which find, in the nearby Glades and waters

of the southwest coast and bay, the food supplies with just the right vitamins for their babies, may I take you in your mind's eye to the scene of some of these great congregations of nesting and roosting birds now guarded by Audubon wardens?

Picture yourself seated comfortably in the thirty-six foot boat "Audubon" anchored off Duck Rock, a little mangrove key on the southwest coast not far below Everglades. It is a July evening and the sun is setting in a burst of golden glow. Great thunderheads tinted lavender and pink tower out of the Gulf of Mexico, and rain squalls, stabbed with lightning, are scattered here and there. The waters of the gulf are like a mirror, absolutely calm. From their day-time feeding grounds in the Glades, there come winging in great Vs and strings thousands and thousands of Egret. Herons and White Ibis. A hundred thousand or more will roost for the night on that tiny key. As they pass, silhouetted against the setting sun, there is no audible sound except the mass whirr of their wings. But there's great commotion in the roost, before they settle down for the night. as though they were gossiping and swapping notes on the day's events.

May I take you to the milky green waters of Florida Bay, studded with many a mangrove key, still bearing visible witness to the devastating effects of the 1935 hurricane? Here the statuesque Great White Heron holds on under protection in its chosen habitat; through the haze, feeding Great Whites. scattered over the vast expanse of shoals, give one the impression of so many white sails on sloops in a race.

There, on a few selected keys, which seem to combine the necessary requirements of extensive marl shoals, with a southwest exposure, the few remaining breeding Roseate Spoonbills or "pink curlews" hold sway. It would be difficult to conceive of a more beautiful sight in nature than this great pink bird with carmine epaulets and bright orange tail against a background of green water, dark green mangroves and bright blue sky with fleecy clouds.

May I take you to your own Kissimmee Prairie, where the raucous calls of the Cranes reverberate across the palm-studded savannahs and the high wailing cry of the Limpkin comes from the river bottoms and the lake edges; where, from a little old gum slough on the Prairie comes the cackle and laugh of the Logcock or "Lord-god," and from its deepest recesses the barks and resonant hoots of an old Barred Owl.

These. ladies and gentlemen, are sights and sounds which delight us, which spell to us the attractions of the American outdoors and which we must contrive to preserve, not only for our enjoyment and benefit but for that of our children and posterity.

At today's meeting of the Soil Science Society of Florida, there has been presented a vast amount of highly important basic data with regard to the underlying rock structures, the character and depth of soil and the water, vegetation and wildlife conditions within the Everglades Drainage District. These, it seems to me, furnish the basis for the adoption of an intelligent land-use plan for the Glades.

I wonder if it is not a very fortunate circumstance that no such plan has been adopted prior to the availability of such information. Those

Plate I

GLOSSY IBIS

The Glossy Ibis is rare in the United States by comparison with its western relative the White-faced Glossy Ibis. Although there remain a few small isolated colonies of breeding Glossy Ibis elsewhere in Florida, the only known sizeable concentration is at Lake Okeechobee, where some two thousand of them repair annually to some grassy islet to nest and along whose wet shores they find livelihood throughout the year.

Although appearing, at casual glance, to be black in color, their maroon, bronze and green plumage proves, on close inspection, to be beautifully iridescent.

Closely related as these Ibis are to the White Ibis, it is not surprising to learn that their nesting habits and food preferences are similar. Eggs of the Glossy Ibis, however, are of a deep robin's egg blue.

The fate of the Glossy Ibis, as a nesting species in Florida, is closely tied to water control policies affecting the level of Okeechobee Lake. It clearly prefers those portions of the lake shore where no hurricane dyke has been built and those grassy islands or shoals out in the lake where there is always a well-watered portion, even at such times as the lake level may be so low as to have shrunken the lake's diameter by many miles.

Eastern Glossy Ibis and White-Faced Glossy Ibis
Two upper figures Eastern Glossy
White-faced Glossy at bottom

From a painting by Roger T. Peterson

Plate II

LIMPKIN

The Limpkin is a Floridian, and the heart of its habitat is in the reedy shores and grassy islands of Okeechobee Lake and the marshland borders of the Kissimmee and St. Johns Rivers and their tributaries. If in such surroundings one hears a wild, wavering, quite human cry, as if from the throat of some agonized creature, it is quite surely the voice of the Limpkin, known locally as "Crying Bird" or "Nigger Boy."

Not content to be a specialist in vocal effort, the Limpkin is highly selective in its diet, which is confined almost entirely to one kind of snail characteristic of the fresh water marshes of Florida. The bird extracts the animal expertly from its shell, as does also the Everglades Kite, a hawk which likewise feeds almost exclusively on this kind of snail. The birds, therefore, are usually found in the same localities, although the Kite has been so reduced in numbers that it is now only found regularly in certain sections of Lake Okeechobee.

The Limpkin builds a platform type of nest among the reeds close to the water and the eggs usually number four. The young hatch covered with black down, as do those of the kindred Rails. In flight there is a noticeable upward flirt of the wings when near the topmost extent of the beat; the only other Florida bird of which this is known to be true is the Florida Crane (not to be confused with the Great Blue Heron, so commonly but erroneously called "Crane").

Dependent as the Limpkin is on specialized wet habitat, it is easy to understand the devastating effect on the Limpkin of drainage and the deliberate lowering of water levels.

LIMPKIN

From a painting by Roger T. Peterson

Plate III

HERONS AND EGRETS IN THE EVERGLADES

It is but a little over a generation ago that the American and Snowy Egrets, the "long white" and the "snowy" of the plume hunters, were on the verge of extinction. As long as there was a market for their plumes, men sought them out as they brought food to their young in the nests, stripped the nuptial plumes from the backs of the adults and left them and their young to die.

The restoration of the Egrets to comparative abundance is one of the outstanding accomplishments in conservation and furnishes incontrovertible evidence that protection pays dividends.

Herons and Egrets exercise wide choice in their diet: fish, frogs, snails, snakes, aquatic insects, grasshoppers, lizards, crawfish — even small rodents. The Ward's Heron is a southern race of the continentally distributed Great Blue Heron. The Little Blue Heron is white in plumage in its first year, and birds in the intermediate mottled blue and white plumage are frequently seen. The Louisiana Heron is not as inclined, as are the other species, to wander northward in the summer after the nesting season is over. The Egrets and Little Blues now occur quite regularly at that time of the year as far north as New England and the Great Lakes, but, long before the northern winter chills arrive, travel unrationed flyways to Florida's warm winter sunshine.

These are the birds that, together with the Ibises and Spoonbills, constitute one of the greatest outdoor attractions in Florida. For survival they are dependent upon ample, watered habitat for food and the kind of nesting cover that they consider requisite.

HERONS AND EGRETS IN THE EVERGLADES

Little Blue Heron (adult)
Little Blue Herons (immature)
Ward's Heron

American Egret
Snowy Egret
Louisiana Herons (immature in middle)

n a painting by Francis L. Jaques

Plate IV

WHITE IBIS

Known also as the White or Spanish Curlew, the White Ibis is a familiar bird throughout Florida, where it constitutes the great bulk of the roosts and rookeries of mixed Herons, Egrets and Ibises. Frequently, when migrating in the spring of the year, these Ibises circle in flight with the precision of regimented troops and glitter and, in turn, disappear in the clear sunlit sky. Such a maneuver is depicted in the illustration on the opposite page.

From their daily feeding grounds in the glades or other marshes, White Ibises throng to roost in long strings and vees, settling for the night in amazing density on small mangrove-studded keys or on an acre or two of clumps of willows or myrtles.

Crawfish, snakes, cutworms and grasshoppers provide most of their menu. The old birds feed the young in the nest by regurgitating, as do all members of the Heron, Egret and Ibis tribes. The eggs are chalky white splotched with brown. The young, curiously enough, are quite black in plumage in early youth.

The continued prevalence of the White Ibis in Florida is clearly dependent upon maintenance of ample, well-watered habitat.

WHITE IBIS

From a painting by Francis L. Jaques

who, beginning in 1904, sponsored the drainage of the Glades undoubtedly meant well. Why did that program not only fail to bring about the benefits envisaged by its sponsors but actually do much damge to the economy of South Florida? I would hold that it was primarily because effort apparently was not made, prior to initiation of the projects, to determine those same basic facts which have been presented at this afternoon's meeting. The hydrological and biological consequences were either not foreseen or were ignored.

Now the information is at hand. Recognition of the need for action is widespread. It would seem that, if no effective action be taken soon, there will be little left in the Glades worth saving. Their destruction has already proceeded a long way on its man-made course. Yet it would not seem too late for cooperative effort, such that those portions of the Glades adapted to agricultural use may be so developed, and those portions not so adapted be properly treated as water storage basins or National or State parks or wildlife refuges. There does not appear to be before you a matter involving any appreciable conflict of interest but, rather, one of translation of a plan into proper legal and administrative form for the best use of the natural assets with which South Florida is now blessed.

The National Audubon Society has devoted much time, thought, money and energy to the protection of the birds and other wildlife in the Glades and on nearby lands and waters, and is therefore vitally interested in the adoption of a wise land-use plan based upon the known scientific facts. In its efforts toward that end, it has fortunately enjoyed, and hopes to continue to be privileged to enjoy, the friendly cooperation of all Florida interests and of the agencies of the Federal government. If such a plan be at last put into effect, the preservation of the wildlife, as well as of the soils, waters and vegetation, will be reasonably assured and the people of South Florida will be benefited through the preservation of natural values of the utmost esthetic, recreational and economic consequence.

SOIL AND WATER CONSERVATION PROBLEMS OF THE EVERGLADES — A Continuation Discussion

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MORNING CONFERENCE — MARCH 17, 1943
10:00 A. M.

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INTRODUCTION

H. I. Mossbarger,[1] *Chairman*

The meeting will come to order. I am happy, under the circumstances of gas rationing and other difficulties of travel, to see such a good attendance this morning. I am sure that quite a number more will be in a little later. It is particularly surprising, under the circumstances, to have so many present this early in the day for a meeting of this nature. I recall a few years ago when small groups of us were gathering around from time to time trying to create an interest in the development of authentic information in regard to the Everglades, we thought we were doing well when we got as many as 12 or 15 people together for this purpose.

For the records of the Soil Science Society, I want, at this point, to briefly mention and acknowledge the value of the work of the Secretary of this organization, Dr. R. V. Allison. It is through his tenacity and through his devotion to the job that this meeting here is possible today. Some time ago, after spending a number of years here in the Glades and becoming so interested in it that he talked it, slept it and ate it, he was called to duty in Washington, and in that work, he so radiated his enthusiasm in regard to this area that it resulted in the Department of Agriculture becoming interested in giving further thought and study to this problem. As a result, we have obtained cooperation and information that otherwise could not have been developed.

Today, we have a number of agencies of the Federal government intensely active in these problems. It is through their cooperation and through their work that it is possible for us to develop the authentic information that is so necessary for us to intelligently consider the problems that now confront us in regard to this great area.

Last year our conferences in West Palm Beach were the first meetings of their kind where we were able to get together and develop a report on the work that was being done by these various agencies, both Federal and local. This meeting this morning is a continuation of those meetings. It has been arranged so that we can have a further report on the accomplishments of those various organizations throughout the past year, and, as far as possible, make an analysis of all this work, so that we can be guided by it in the future.

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[1] President, Soil Science Society of Florida, Miami.

You will note that the program has been organized with as logical sequence as possible in the subject matter for purposes of clarity. This should give us the requisite information in such form that the layman can understand it and have a clear idea of what is going on in the Glades.

This work is all so connected and interlocked, that it would not be possible to do this job without these various agencies cooperating as fully as they are. I must say that it is very gratifying to work with these men and see the feelings they have of comradeship and of willingness to work with each other in their various branches. I have never seen groups work together with so little friction, and I don't believe there is a single one of them who is not willing to go the limit in cooperating and doing everything in his power to coordinate this work—very often subjugating his own ideas in order to make a smooth running effort. It is really stimulating to be able to make such a report. I am confident that some of you who are not so familiar with this work will realize before the day is over that the above is a true statement, and that we are on the road to great things here in the Everglades as a result of these studies.

There is just one further thought that I want to leave with you while we are here today considering these vast problems, and that is, there already has been spent at least 50 million dollars on the general development of this area, thus making of it one of the most important in the economic life of the State of Florida, if not of the entire nation. In this connection it is important to remember that action taken in these meetings today may go far in governing the future success of this tremendous project.

With those few remarks we will now start the program this morning with a "Summary of Three Years of Surface Water Studies in the Everglades" by Mr. G. E. Ferguson, District Engineer of the U. S. Geological Survey, Ocala. Mr. Ferguson.

SUMMARY OF THREE YEARS OF SURFACE WATER STUDIES IN THE EVERGLADES

G. E. Ferguson [1]

In a contribution to an earlier publication of the Society [2] the writer described the objectives and plans of the Water Resources Branch of the Geological Survey, U. S. Department of the Interior [3] relating to systematic studies of the surface water of the Everglades and the collection of other basic hydrologic data in that area since the autumn of 1939. The data that have been collected and compiled during the three calendar years 1940 to 1942 cover too short a period of time to permit the formation of accurate conclusions affecting the design of water control works or general development in the area. The records do, however, indicate certain interesting and informative characteristics that will be immediately useful in connection with long-range planning for the Everglades. Accordingly, this paper will deal primarily with a discussion of these characteristics as they have partially revealed themselves during three years of study. As in the earlier article [2] the characteristics will be grouped under the major hydrologic factors of rainfall, evaporation and transpiration, and runoff. Data [4] pertaining to the Kissimmee River basin and Lake Okeechobee will also be included because the water resources of these areas are integral parts of the Everglades water problem.

RAINFALL

Seasonal distribution of rainfall is one of its most important characteristics from the standpoint of water control. This seasonal characteristic is illustrated by the monthly rainfall for the past several years as shown graphically in Figure 1 and, although the period of record is short, the wet summer and comparatively dry winter seasons are clearly shown. The reason why drought conditions usually exist in the spring of the year following the several fairly dry fall and winter months is partially explained by this graph.

The occasional large areal variations during months of heavy storm rainfall such as occurred in September 1941 and April 1942 are also shown in this figure. Storm areas are sometimes so small that rainfall is concentrated over only a portion of the Glades, leaving widely varying conditions of runoff.

Daily variation in rainfall within the month owing to heavy storm falls during a period of a few days is pertinent primarily to drainage

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[1] District Engineer, Geological Survey, U. S. Department of the Interior, in charge of investigations of surface water resources of Florida, since 1941. (See also Proceedings Soil Science Society of Florida, Vol. IV-A, p. 77, 1942.)

[2] The Plan and Progress of Recent Surface Water Studies in the Everglades, Proceedings Soil Science Society of Florida, Vol. IV-A, pp. 77-85, 1942.

[3] In financial cooperation with the cities of Miami, Miami Beach and Coral Gables, and Dade County; also with Everglades Drainage District since April, 1943.

[4] Records of stream flow, stage and rainfall are also being collected in the Kissimmee River basin, other tributaries to the Lake, and on the main control canals by the Geological Survey with financial support by Corps of Engineers, U. S. Army.

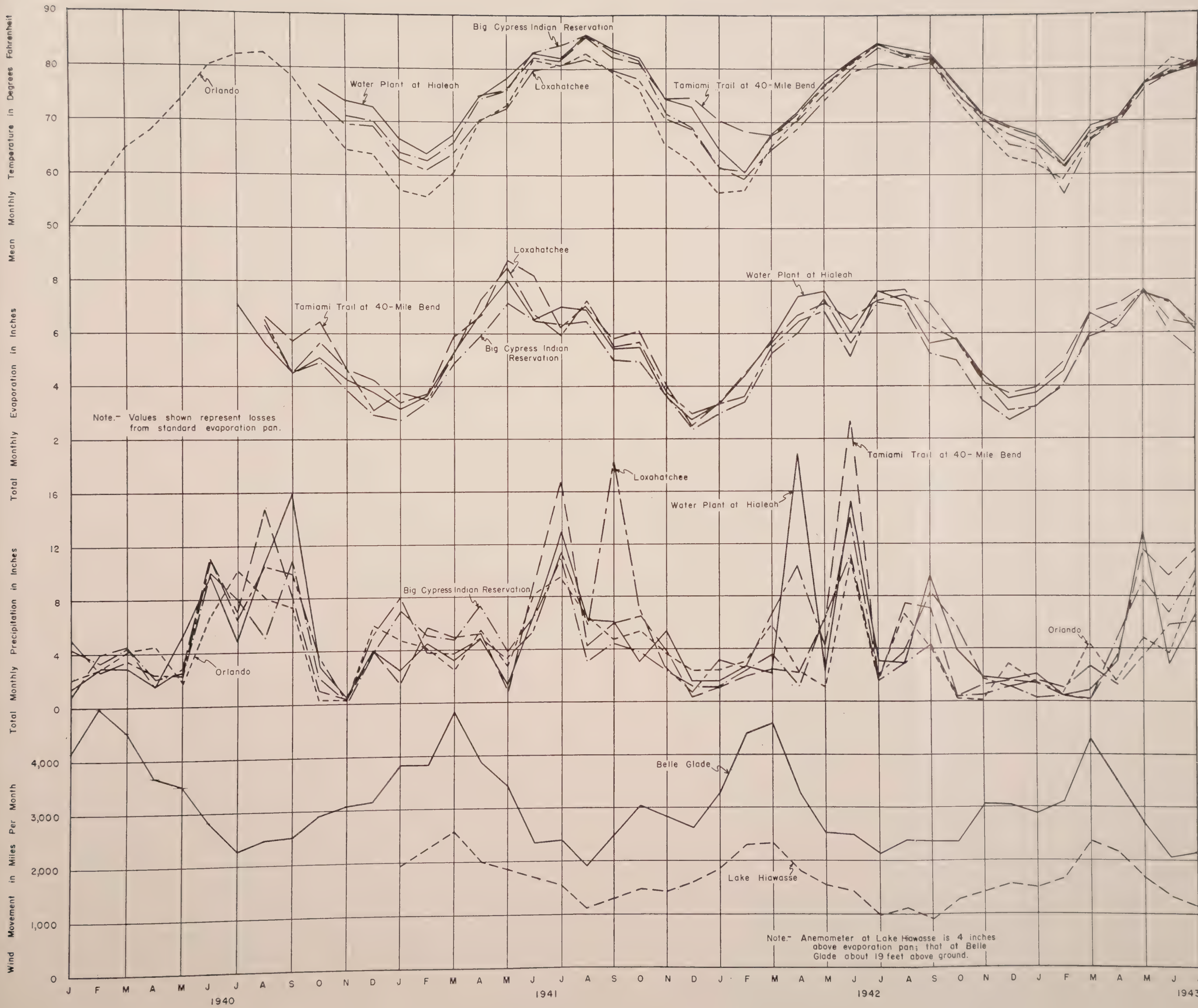

Figure 1.—Graphs showing climatological data for Southeastern Florida.

problems. Such storms are often associated with hurricanes and tropical disturbances, and are, therefore, most likely to occur in that season when water supplies in the Glades are already large. Consequently the flood control problem is increased.

The hourly variation within the day is of secondary importance in water control problems in the area, primarily because of the level topography and the slow runoff rates. The high percentage of short, concentrated periods of rainfall show the effects of hourly variation.

The areal distribution of rainfall over the Everglades is a matter of continuing interest, and although varying statements regarding it have been made, the rain gage network before 1940 was not sufficiently complete for the collection of data that would show accurately the relative rainfall over the various areas. Several additional years of record will permit such an evaluation. A decrease in rainfall from the coastal ridge toward Lake Okeechobee is indicated from U. S. Weather Bureau records for the several older rain gages along the coast and in the vicinity of Lake Okeechobee. Rainfall in the Kissimmee River basin tends to be somewhat less than that over the Everglades, with the seasonal variation approximately the same.

EVAPORATION AND TRANSPIRATION

Approximately three-fourths of all the water that enter the Everglades, both from rainfall and through the canals from Lake Okeechobee, leaves the area by evaporation and transpiration. This is sufficient justification for evaporation studies, and indicates their value in the design and operation of water control systems. Evaporation is helpful in drainage operations as it removes standing water in the Everglades, in some cases more effectively than by the canals. However, during periods of drought these losses greatly increase the problems of maintaing water levels sufficiently high for proper protection and use.

Figure 1 shows graphically the total monthly evaporation losses from several standard pans in and near the Everglades. Such graphs indicate that the greatest evaporation usually takes place in the spring of the year when water supplies are generally the lowest and maintenance of proper levels is the most difficult. This unfortunate condition is owing to the fact that the rate of evaporation is influenced by temperature, and wind. Graphs of mean monthly temperatures and of wind movement are also shown in Figure 1. These graphs indicate that, from the season of lowest evaporation in December or January, the rate of evaporation increases with increases in temperature and wind movement until about March, after which the evaporation losses continue to increase with rising temperatures, although the wind movement begins to decrease. Such a higher trend continues until broken by the beginning of the summer rainy season, usually in May or June, when the higher humidity causes an immediate reduction in the evaporation rate. After the end of the summer rains the rate of evaporation continues to decrease with lowering temperatures until the end of the calendar year.

Unlike precipitation, no appreciable areal variation in losses from evaporation pans in the Everglades is revealed by a study of the records collected so far. Slight differences that are indicated may be partly

owing to variations in the equipment, slight differences in exposure, the method of taking observations, or other causes.

In summarizing the data it may be said that the evaporation (pan) losses vary from a seasonal low in December or January to a high of from two to three times the low value just prior to the rainy season, usually in May or June. The actual evaporation (and transpiration) over the Everglades and southeastern Florida may vary from the pan values by a small fraction or as much as 100 percent or more, depending upon available water on or near the ground, and the presence and type of vegetation. A condition in which the water levels are below the zone from which they might be drawn to the surface by capillarity or by plant roots and in which soil moisture is well depleted would result in a comparatively small evapo-transpiration loss. The opposite extreme would be a condition of water standing in a thriving area of saw-grass or other vegetation having a large transpiration capacity, with water losses both directly from the water surface by evaporation and through the vegetation by transpiration.

RUNOFF

Runoff, which is the term applied in general to the surface flow of water from an area, has complex characteristics in the Everglades. The canals have a very low gradient and are excavated partly in rock of varying but relatively high permeability. As a result the direction of flow is influenced by the water table as well as by land gradients, and the water is almost constantly passing into and out of storage in the rock, and to a limited extent the muck, through which these channels are cut. Most efficient usage of the canals requires a knowledge not only of the amounts of water to be carried from one area to another for drainage or utilization, but also of the water levels of the areas adjacent to the canal reaches in order to allow for large losses or gains en route.

In some areas control structures in the canals are only partially effective as retention dams owing to leakage through the rocks around these barriers. Such leakage has been found to leave and reenter the channels in appreciable amounts several hundred feet above and below such controls.

The heads of the arterial canals serve to move water both into the area from Lake Okeechobee for irrigation and out of the area into Lake Okeechobee for drainage. Flow records collected during the three-year period ending December 31, 1942, show that considerably more water passes from the Lake into the Glades than in the opposite direction through the West Palm Beach, Hillsboro and North New River canals. In the Miami Canal, however, the predominant discharge is toward the Lake.

In the lower or coastal ends of the canals where control structures regulate the outflow, the greatest amount of water is discharged by the West Palm Beach Canal with the North New River, Hillsboro, and Miami canals each discharging roughly half that for the West Palm Beach Canal. These discharge values are given in the following section.

HYDROLOGIC RELATIONSHIPS

In the design of water control works in the Everglades it is most desirable to have available not only adequate data regarding rainfall, evaporation, and runoff, but also as complete a knowledge as possible of the relationships between these factors. A record of flood flows in an arterial canal cannot be effectively applied in design of improvements to that canal without a knowledge of the characteristics and amounts of the rainfall which caused those conditions. It is also true that rainfall records alone do not permit effective canal design. Likewise, in providing facilities for watering large unused areas for fire and oxidation control, it is essential to know not only the capacities of the canals carrying water to these areas, but also the evaporation losses which largely indicate the quantities of water to be transported. To be of greatest use in development, these hydrologic studies should furnish an inventory of the water supplies at all locations and a record of the manner of movement of these supplies from one area to another.

During the past three years a large amount of data [5] on water resources in the area have been collected and hydrologic relationships are being established. The brief summary of these data that is presented below is intended to furnish a general description of the water resources of the area. It is based on average annual values obtained from records for the calendar years 1940-42 inclusive. The annual values will be revised as the collection of data continues until such a time as they represent the average conditions over a long period. They will then be of greatest use in the design of water control works.

Of the 52 inches of rain (average annual) which fell in the 3,260 square miles of Kissimmee River basin, the losses due to evaporation and transpiration were so great that the equivalent of only a little over 8 inches of this water actually passed down the Kissimmee River into Lake Okeechobee. This would constitute an average flow into the Lake of about 4,000 acre feet per day but actually this flow varied from a minimum of 1,900 [6] acre feet per day on May 29, 1940, to a maximum of 9,220 acre feet per day on February 28 and March 1, 1942. An unknown but probably relatively small amount of water also passed into the Lake from the Kissimmee River basin by natural underground movement.

Lake Oeekchobee received, in addition to this flow from the Kissimmee River, a substantial amount of water from other minor drainage basins and a large amount from rainfall on the Lake surface. Assuming a Lake basin of 800 square miles a "balance sheet" for the lake's water would be as follows:

	Mean Annual Gain (Inches)	Mean Annual Loss (Inches)
Inflow:		
Kissimmee River	35	
Fisheating Creek	5	
Indian Prairie Canal	2	
Taylor Creek and other inflow	12	

[5] These data will be presented in a comprehensive manner in a report now under preparation by the U. S. Geological Survey on the water resources of Southeastern Florida.

[6] The minimum flow since records were begun in 1930 was 458 acre feet per day on May 18, 1932.

Rainfall on basin	50	
Evaporation and transpiration [7]		46
Outflow in St. Lucie and Caloosahatchee Canals		54
Outflow (net) in drainage canals		6
Total	104	106

The close balance shown above between gain and loss is affected somewhat by the fact that storage in the lake was greater at the beginning than at the end of the three-year period by an amount equivalent to over 19 inches over the area. This water loss when reduced by the differences in the above tabular totals amount to a net loss of over 4 inches per year over the area which is equivalent to about 550 acre feet per day. Inaccuracies in evaluating the actual losses in evaporation and transpiration over the Lake basin may account for errors which may be sufficiently large to either cancel or more than double the net loss indicated above. Because of this condition the only possible conclusion to be drawn from these values is that either there is no great underground movement of water into or out of the Lake or that if such a movement exists the amounts of such inflow or outflow do not differ greatly from each other. Longer periods of records will be necessary to evaluate these factors better and to determine the comparative rate of losses under the levee around the south and east shores of the Lake at the high and low Lake levels.

In the Everglades [8] the amount of water received from the Lake was equivalent to about one inch over the area. An additional annual average of 57 inches was added from rainfall making a total of about 58 inches. From this total only 14 inches was drained off through the canals because of the large evapo-transpiration losses. In addition, some small amount may have passed into and out of the area through the ground. The amounts of water carried out of the Glades by these arterial canals is as follows:

	Inches over area (annual)	Acre-feet (annual)
West Palm Beach Canal	4.5	936,000
Hillsboro Canal	2.1	446,000
North New River Canal	2.4	504,000
Miami Canal	2.6	541,000
Tamiami Canal		
Outflow to south	1.4	288,000
Flow to Biscayne Bay	.8	160,000

[7] This value computed by applying a coefficient of 0.78 to weighted average of 5 evaporation pans operated by the Corps of Engineers, U. S. Army at locations on the shores of the Lake. To allow for additional losses due to transpiration, the evaporation loss was doubled over the 100 square miles of swamp on the Lake shores. The value of 46 inches shown is approximate only but is believed to be not greater than 15% in error.

[8] For hydrologic computations it is considered as an area of 3,900 square miles lying south of Lake Okeechobee and St. Lucie divide, west of Atlantic coastal ridge, north of Tamiami Canal and east of western boundary of Everglades Drainage District.

CONCLUSIONS

After the past three years of study of the water resources of the southeastern Florida area the writer is convinced that, although a considerably greater degree of water control than now provided for in the Everglades is possible. the development of such a control is a complex problem which may take several successive stages of alternate construction and scientific trial operation before complete success is achieved. Because of the flat topography and the resulting wide effects of stage control at any one point, each of the structures or development works would best be designed in accordance with a broad or long range plan to prevent both adverse conditions in an adjacent area or future problems after additional development in the same area.

The water resources of the area are not unlimited, especially in periods of drought when evaporation losses from Lake Okeechobee are usually at seasonably high values. The successful control of high water tables on the Everglades during the spring months will require large amounts of water and will necessitate careful planning and the use of judicious water conservation measures if such water is to be available. This is especially true when drought conditions may persist for several months.

CHAIRMAN MOSSBARGER:

Thank you Mr. Ferguson. Too often we fail to recognize the value of water and the very great importance of the studies the U. S. Geological Survey is making along this line in this section of the State. Certainly this work is bringing together vital information that is entirely indispensable to the building of a sound water program for the future.

This brings us quite logically to our next subject "Progress Report on a Topographic Reconnaissance of the Everglades Drainage District" by Mr. Albert R. Stephens, Assistant Drainage Engineer with the Soil Conservation Service of the U. S. Department of Agriculture stationed in Fort Lauderdale. Mr. Stephens.

PROGRESS REPORT ON A TOPOGRAPHIC RECONNAISSANCE OF THE EVERGLADES DRAINAGE DISTRICT

Albert R. Stephens [1]

The Everglades Drainage District embraces approximately seven thousand square miles, lying in Townships 37 to 59 and between Ranges 29 to 43 in southeastern Florida. This area includes Lake Okeechobee, the Everglades, part of the Big Cypress Swamp, and the marginal sandy lands. By far the larger part of the District is still in its virgin state, much of it having been unsurveyed until the inception of the Everglades Project.

Though several agencies have surveyed parts of the District, they were comparatively small areas, often based on different horizontal and vertical controls. Hence little was known of the District as a whole in regard to ground elevations, soil depths, drainage divides, ground subsidence, boundaries of timber lands, prairies, and peat lands, or of the limits of the areas having potential agricultural value, which is dependent in considerable part on soil depth and sub-soil formation. Naturally, any plan of conservation must be governed by such information.

In the early part of 1940 a topographic reconnaissance was begun. As the survey progressed it became apparent that it should determine not only the surface features of the District in relation to established land lines, but also the subsurface conditions that would influence land-use planning and water-control construction. The reconnaissance, therefore, was broadened to include measurement of the depth of the peat and a record of the character of the underlying formation. The extent of this reconnaissance, to date of March, 1943, is well shown in Figure 1.

During the middle of the nineteenth century the General Land Office, then under the Treasury Department, started the subdivision of lands in southeastern Florida into townships six miles square, numbered north and south in ranges numbered east and west. The origin for numbering these subdivisions is at Tallahassee, and they are designated by their distance and direction therefrom. Hence all townships in South Florida are "south" and all ranges "east". It is not always possible, however, to run a continuous survey from the initial point. Natural barriers, such as the Everglades, which at that time were largely impenetrable, for the most part, left unsurveyed areas. In completing the subdivision of these areas, the closing of township boundaries did not coincide with boundaries of previously established townships, leaving gaps containing fractional sections which are designated as "lots". There are several north-south and east-west hiatuses in the Everglades Drainage District.

Determination of the true relation of townships, one to another, and the relation of all natural and artificial features to land lines, is as neces-

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[1] Drainage Engineer for South Florida Drainage and Sub-Drainage Districts, 1925-1930; Engineer, Soil Conservation Service in North Carolina, 1934-1940; Assistant Drainage Engineer in charge of topographic surveys for the Everglades Project, U. S. Soil Conservation Service, since 1940.

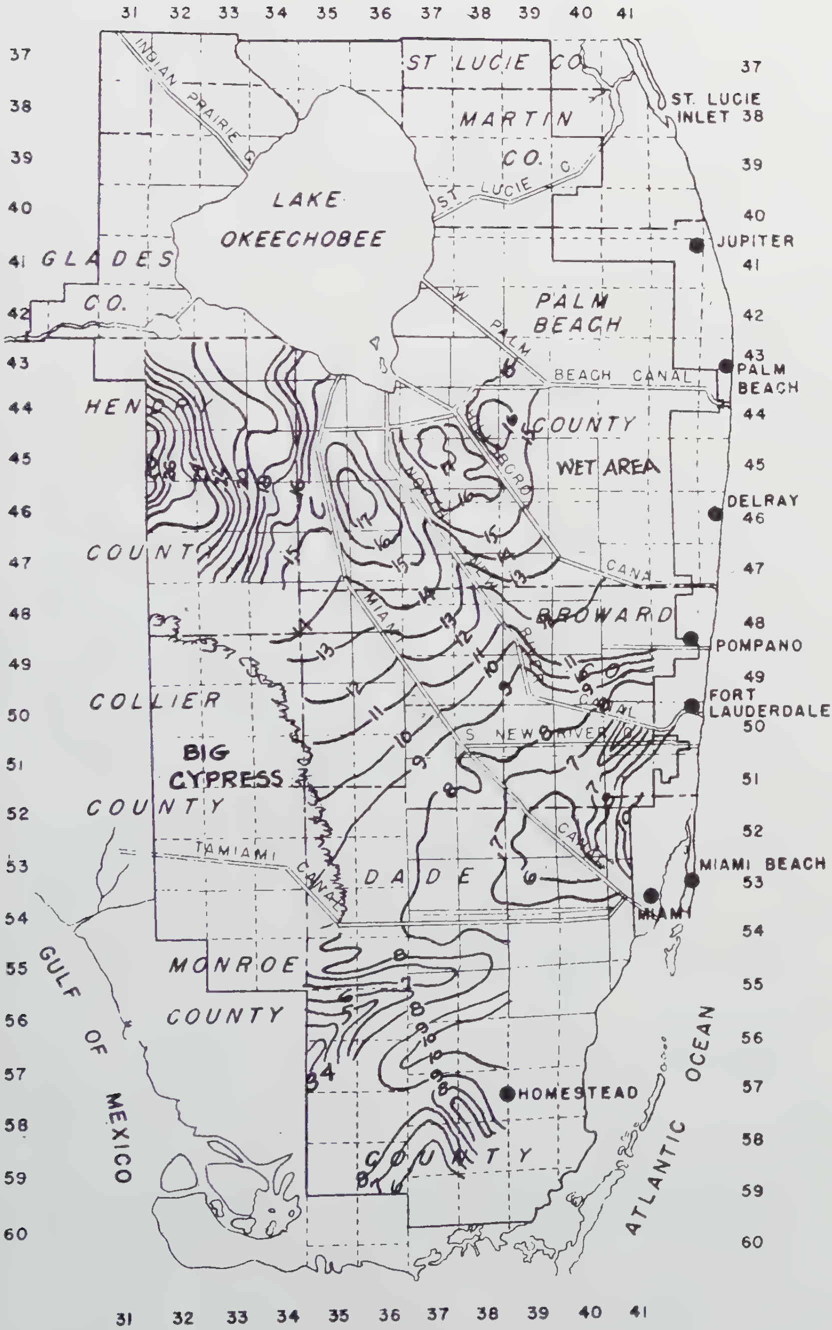

Figure 1.—Contour map of the Everglades Drainage District as developed to date of March, 1943.

sary to the complete survey as the 1,500 miles of levels run through and around the Glades to determine its elevation. Because the direction of a road or canal follows a cardinal point of the compass by no means indicates it follows a land line, even though an established land corner may be found beside it. A hiatus, an offset, or a change in bearing of the line may change the relation considerably. Topographic lines do not necessarily follow land lines, but their locations have been related to existing land corners, the positions of which are known, or are determined by Coast and Geodetic triangulation stations.

A vertical-control line or series of bench marks through or near the area to be surveyed is of primary importance, hence was the first consideration. Bench marks established by the Coast and Geodetic Survey's second-order level lines from West Palm Beach to Fort Myers and first-order line down the East Coast constitute the base from which vertical-control lines were run. Their mean sea level datum is used, plus 1.44 feet for conversion to Okeechobee or Punta Rasa datum.

Highway 26 along the North New River Canal was taken as a base line for all topographic lines run between the Miami Canal and the Hillsboro Canal south of Okeelanta. Bench marks were established on State Road Department culverts approximately two and one-half miles apart from South Bay to Fort Lauderdale and down Highway 26-A to Miami.

Upon completion of the control line, surveys in the peat were undertaken. There are three kinds of terrain in the District which determine the method of transporting crews and equipment. In shallow peat or on sand prairies, wheel vehicles or "Glades buggies" are generally used. Locally these are sometimes called "Marsh buggies." They are specially powered and equipped for traversing areas for which no other type of equipment is suitable. Some are converted, light-weight trucks with special-type wheels; there may be two wheels with steel rims or several with rubber tires on the rear, and dual wheels in front. Rubber-tired wheels are necessary in the rock country south of the Tamiami Trail in dry weather. A heavy-duty rear end is powered through two transmissions that furnish several ratios of speed; double reverse, for example, gives a forward motion that is hardly apparent but which is often the only speed that will come through a bog hole instead of staying in it. The type of glades buggy that has proven the most successful in the Everglades, however, has a specially designed double-drive rear end with six wheels on each side.[1]

In the deep peat areas and dense growth of myrtle along the canals, the crawler-type tractor with extensions on the tracks is the most dependable. They have been found, often by sad experience, the most likely to stay on top of the peat, and the least likely to break down. In wet areas of the northeastern and southwestern parts of the District, an "Air-boat" or light scow driven by an aeroplane propeller is the only means of travel over the soft loblolly. In any case the conveyance must be adequate to transport all necessary survey and camp equipment for a week's operation, as night is spent wherever it overtakes the survey

[1] Trials with the Army's cargo-carrying "Weasel" made before this Proceedings had gotten through the press proved it by far the most efficient and satisfactory vehicle used to date on the wet marshy sections of the Everglades.

crew, which is often in regions where footprints of white men are not to be found. Some of the equipment used and the conditions under which the work is being done are well shown in Figures 2 to 6.

Topographic lines were planned to follow appropriate township boundaries, to run across and through subsided areas and adjacent to roads, canals, and cultivated land. Bench marks consisting of iron pipes with bronze caps suitably marked are set at about 3-mile intervals along the lines. On lines not in the area covered by township subdivisions, bench marks are set only where adequate description in relation to some existing mark is possible.

Ground elevations, peat depths, and kinds of vegetation have been recorded over approximately 750 square miles between the Miami and the North New River Canals. Lines were run west from the North New

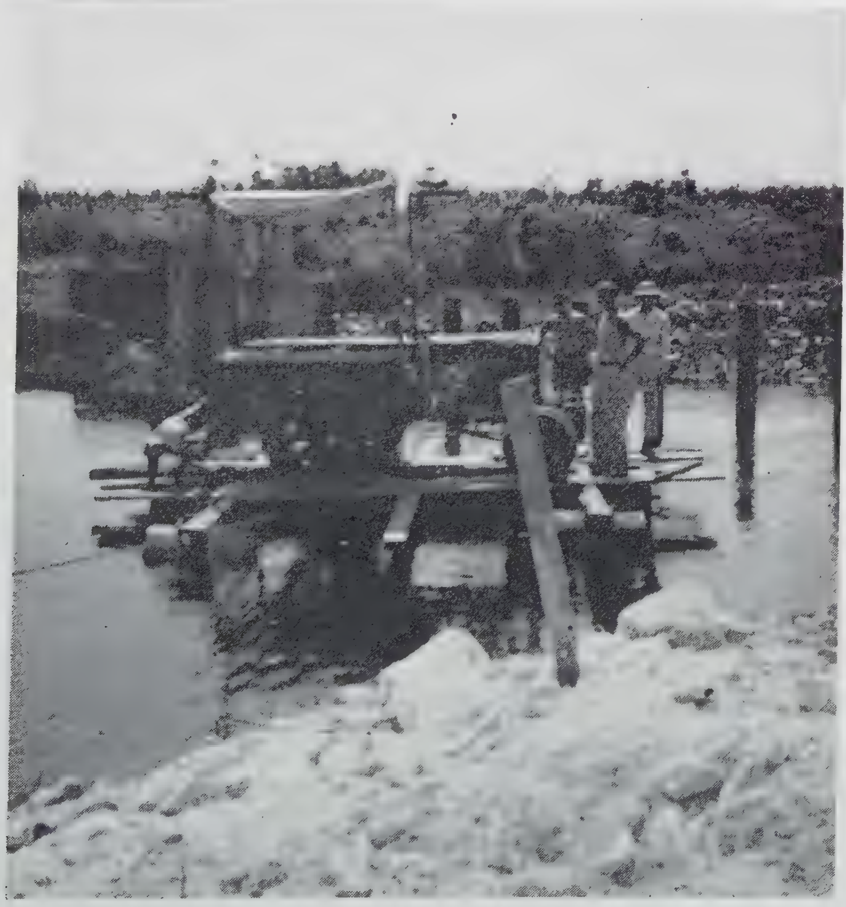

Figure 2.—One of the first "Glades Buggies" used in the Everglades survey, 1940, crossing the North New River Canal on an improvised pontoon made of a 4′ x 10′ scow, four empty gasoline drums and a few 2″ x 6″ timbers. The control dam at Dyke B is shown in the background.

River Canal on township lines; one was run southeast from the Bolles Canal for a distance of 35 miles on the "ridge", or highest part of that area: and two lines parallel to the North New River Canal at 1 and 2 miles therefrom. The highest elevation recorded in this area was 17.2 feet, 6 miles south of the Bolles Canal and 4½ miles west of the North New River Canal. From this point the Glades drop away to the southeast to an elevation of 5.5 feet in the lower extremity. Adjacent to the canal, the terrain drops to the north from 14.4 at Dike B, 12 miles south of the Bolles Canal, to 13.8 feet at that canal. This reverse grade is the result of subsidence caused by cultivation in the Okeelanta area. The extreme of subsidence resulting from drainage, fire, and cultivation was observed 4 miles south of the Bolles Canal adjacent to the North New River Canal, where the elevation of the peat is 3.3 feet lower than it is 5 miles west. Subsidence along the Miami Canal is slight compared to that along the North New River Canal. The greatest depth of peat in this area was 9.0 feet, 1 mile south of the Bolles Canal and 5½ miles

Figure 3.—Tripods with extra-long, 8-foot legs proved necessary in the soft, spongy peat to permit access to the instrument by the operator. Each leg of the tripod is imbedded in the soil about twelve inches to get a solid footing. Photo taken in December, 1941, on the west margin of the Glades. (Ed. note: Engineer Stephens at the instrument.)

west of the North New River Canal. In contrast with this, the depth was only about 2 feet at the junction of Highway 26-A and the South New River Canal, some 40 miles to the southeast. Sawgrass ranging from 1 to 6 feet high, lilies, ferns, and myrtle are characteristic vegetation. Except for a few deer observed in the myrtle on the ridges of the south, this area is practically devoid of wildlife.

The area east of the North New River Canal, including lands adjacent to the Hillsboro Canal and south of Highway 25, embraces approximately nine hundred and thirty square miles, of which about half is of such character that topograhic reconnaissance is impracticable. Lines were run by Glades buggies and tractor over about 400 square miles. The Loxahatchee peat area along the east portion will have to be surveyed by air-boat, and one line is proposed to be run by meandering some fifteen miles to complete a profile across the Glades. The highest elevation recorded in the sawgrass of this area was 17.2 feet, in the northeast corner of Township 44 of Range 37; the lowest was 8.0 feet, 40 miles to the southeast on the North New River Canal in Range 40. The greatest depth of peat recorded in this area was 10.8 feet, 2 miles

Figure 4.—A 50-HP, Caterpillar tractor with 5-foot, wooden extensions bolted to the steel cleats of its "tracks". About 90 percent of the topographic surveys in the Everglades are being accomplished with this type of transportation. Photo taken November, 1941.

west of the Hillsboro Canal on the south line of Township 44: the least depth was 1.5 feet, over sand at the intersection of the North New River Canal and the east line of Range 40.

West of the Miami Canal, southward from Clewiston to the Hendry-Collier County line, approximately seven hundred and fifty square miles were embraced in the reconnaissance. Surveys in this area were made from the Clewiston Work Unit office, and were based on the Indian

Figure 5. A 30-mile, topograhic line between the North New River and Miami Canals that has been run down by a Caterpillar tractor equipped as shown in Figure 4. The man in the background is the Rear Chainman and the man standing in the foreground is setting a stake that is being ranged in by the engineer on the tractor. The man sitting on the sled has completed his soil-depth probings and is preparing flags over which the lime is ranged. The vegetation is a practically pure stand of sawgrass.

Service (Devil's Garden) Road for control. The west edge of the Glades was located, dividing the sand lands from peat lands, the former being roughly three times the latter. The timber line, dividing the saw palmetto prairie from the pine land lying in Townships 44 and 45, also was located. A line running south from Clewiston 2 miles west of the Palm Beach Hendry County line for 35 miles, with bench marks established every 3 miles, served as a tie for lines run between the Indian Service Road and Miami Canal. The highest elevation of the peat in this area was 19.2 feet recorded 1 mile south of the south line of Township 44, 2 miles west of the Palm Beach-Hendry County line. The terrain falls away to 14.7 feet where the peat runs into the sand prairie, 2 miles north of the southeast corner of Hendry County. The greatest depth of peat was 9.0 feet, 2 miles west of the Palm Beach-Hendry County line on the south line of Township 44, Range 34. The boundaries of wooded

Figure 6.—A typical Glades fire, with which engineering parties have to contend during the dry season, that is surging forward under a moderate wind. Photo taken during the Spring of 1941, 4 miles south of the Bolles Canal along Highway 26.

areas, peat lands, and prairies were located relative to section corners.

West and south of the Miami Canal, in Broward, Collier, Dade, and Monroe Counties, the Everglades Drainage District embraces about 2,700 square miles, including the Big Cypress, the Everglades National Park, the Seminole Indian Reservation, and the sand area along the east coast south of Miami. One survey line was run across the Glades adjacent to the Tamiami Trail. Along this line the elevations range from 7.1 feet in the center of the Glades to 10.8 feet at Miami on the east coast and 9.8 feet at the Collier-Dade County line on the west. The depth of peat varies from a few inches to 3 to 5 feet in scattered areas. Three lines have been run south from the Tamiami Trail. One extends 20 miles south through Range 35, on which the lowest elevation is 4.0 feet in the northwest corner of Township 57. A line along the west side of Range 39 rises from 7.4 feet elevation at the Tamiami Trail to 10.8 feet, 14 miles to the south. Through Range 36 a line meanders 26 miles from the Trail to the Pine Island Road, thence east eight miles to Royal Palm Park. The entire line for the greater length is over sharp rock pinnacles, soft sloughs, marl, and spots of peat. The vegetation was predominantly needle grass, scattering sawgrass, and bay heads. Elevations ranged from 8.5 feet at the Trail to 7.5 feet, 6 miles south, and 6.5 feet through the sloughs southward for 16 miles to Station 1280, where the rockland again is encountered, and between 7.5 and 8.5 feet through pineland, saw palmetto, and needle grass prairie to Pine Island Road. To complete the survey in Collier County will require one line north from the Tamiami Trail along the Collier-Dade County line to the southwest corner of Township 49, to tie in the line from Clewiston and to determine the west edge of the Glades, the boundary of the Big Cypress, depths of peat, and the elevations of ground surface.

A base map of the Everglades Drainage District is being constructed on transverse Mercator projection to a scale of 1:126,720 (1 inch equal 2.0 miles). Plane coordinates of the Coast and Geodetic Survey triangulation system in southeastern Florida fix the location of control points with section and township ties on which ground features from surveys and aerial photographs are based. On this map will be recorded ground elevations and depths of peat at 1-mile intervals, with locations and elevations of bench marks, thus furnishing information necessary for geologic and economic studies as well as for engineering planning. Such a map is also necessary to record much of the research data now being gathered, and upon completion will reflect, to a great extent, the accomplishments of this project.

Chairman Mossbarger:

Thank you Mr. Stephens. From the nature of your work it is easy to understand why you have to find ways and means as well as a will to get through the Everglades in the accomplishment of the very important task upon which you are engaged.

The next discussion is divided, logically enough, into two parts, the first dealing with further studies of geological conditions underlying the Everglades region and the second covering the relation of these conditions to soil and water conservation operations. The first phase, "Additional Notes on the Geology and Ground Water Conditions of southern Florida", has been prepared for the record by Messrs. Garald G. Parker and Nevin D. Hoy of the U. S. Geological Survey in Miami and will now be presented by Mr. Parker.

FURTHER STUDIES OF GEOLOGICAL RELATIONSHIPS AFFECTING SOIL AND WATER CONSERVATION AND USE IN THE EVERGLADES

Part I

Additional Notes on the Geology and Ground Water of Southern Florida [1]

GARALD G. PARKER [2] and NEVIN D. HOY [3]

INTRODUCTION

BACKGROUND.—This paper is a result of further studies of the geologic and hydrologic characteristics of the water bearing formations in southern Florida being made as part of a comprehensive investigation of the water resources of this area by the Federal Geological Survey in cooperation with Dade County, and the Cities of Miami, Miami Beach, and Coral Gables. The earlier implications of the work were reported upon last year by Parker [4] in a preliminary paper before this Society. In that paper it was noted that in order to obtain data to be used by the Soil Conservation Service in evaluating land capabilities, and in designing and placement of structures for control of the water table, muck fires, and soil subsidence, it was planned for the Geological Survey to cooperate with the Soil Conservation Service in the drilling of 15 test wells at selected sites in the Everglades. Furthermore, this drilling would give the Geological Survey a better coverage on the geologic and hydrologic characteristics of the formations which have a direct bearing on the water supply in the Miami area.

These fifteen wells have been drilled since then, pumping tests conducted, samples of rock and water at different depths collected, and subsequent laboratory examination made of the cuttings, fossils, and water. In addition, further progress has been made in the studies of data and materials collected in the drilling of many other exploratory test wells put down by the Federal Geological Survey prior to the above mentioned fifteen wells. From this work certain conclusions have been reached, and it is the purpose of this paper to present them to the Society.

ACKNOWLEDGEMENTS.—The writers are indebted to many persons, especially to fellow workers in the Survey, and to cooperating officials

[1] Prepared by the Geological Survey, United States Department of the Interior, in cooperation with Dade County and the cities of Miami, Miami Beach and Coral Gables.

[2] Geologist in Charge, Geological Survey, U. S. Department of the Interior, in charge of geological field studies and research in the Southeastern Florida Water Resources Investigations since, 1939, and of Ground Water and Geologic Investigations in Southern Florida since 1943.

[3] Assistant Geologist, U. S. Geological Survey, Assigned to the Miami Office since 1939.

[4] Parker, Garald G. Notes on the Geology and Ground Water of the Everglades in Southern Florida. Soil Science Society of Florida, Proc. Vol. IV-A, pp. 47-76, 1942.

of Dade County and the cities of Miami, Miami Beach, and Coral Gables. Among those of the Federal Geological Survey whose help is deeply appreciated are O. E. Meinzer, under whose general supervision this work was done, and V. T. Stringfield, who directly supervised the research; C. Wythe Cooke has worked in the field on the geology of this area and has been associated with the senior author of this paper in developing many ideas here presented concerning the geologic history; Julia Gardner, Lloyd Henbest, and Joseph A. Cushman have identified fossils; S. K. Love and Herbert Swenson analyzed water samples; and Ross A. Ellwood prepared the illustrations. Others who have aided are H. G. Richards of the Academy of Natural Sciences, Philadelphia, who identified some of the fossils; and C. Kay Davis and John C. Stephens of the Soil Conservation Service, who have been especially helpful by arranging for and helping with the drilling of the fifteen wells, in supplying equipment for transportation in and out of hitherto inaccessible parts of the Everglades, and by offering valuable comment and criticism. The airphoto maps made for the Soil Conservation Service were of great aid in the preparation of the map showing directions of surficial drainage.

GEOLOGIC HISTORY

General Considerations.—The history of the earth is written in the rocks, but it is not always easily deciphered because in no place is a complete sequence of pages and chapters to be found. Rather, they are scattered all over the earth, or some may even be missing entirely, and the geologist must search everywhere to piece them together. The chapters of this book are the rock units that are called formations, and the pages are the individual members, or layers within the formations. The characters are many-fold: they may be fossils of animals which lived and died during the time of deposition of the formation; they may be ripple marks in the sand or rain-drop marks in the ancient mud now turned to stone; they may be pebbles arranged in a fashion indicating that a long since vanished stream once flowed in a certain direction there; they may be one thing or another, but all have their part in telling the story.

Here in southern Florida only relatively young rocks are penetrated in the drilling of the deepest water wells; and the oldest of these rocks do not antedate the uppermost Eocene limestone, which was deposited possibly fifty million years ago. A few wells reach into the Miocene rocks, many into the Pliocene (especially along the Atlantic coastal ridge) and many more are developed in the Pleistocene, or even in the Recent materials.

When one tries to date specific geological events in years he is almost attempting the impossible, so the geologist would rather divide time into great divisions and lesser ones, and still lesser ones, based principally upon the type of life existent then as shown by the fossil record in the rocks. Thus geological time is divided into eras, periods, epochs and ages and only those few dates are listed that have been well established by dating from the best geological time clock, the slow, steady, apparently unchanging rate of disintegration of the radio-active minerals uranium

and thorium. By this means it has been reckoned that the age of the earth is about 1,850 millions of years.[5]

Other (and less reliable) means have been devised to date geological events, based on the amount of salt in the sea, the known rate of sedi-

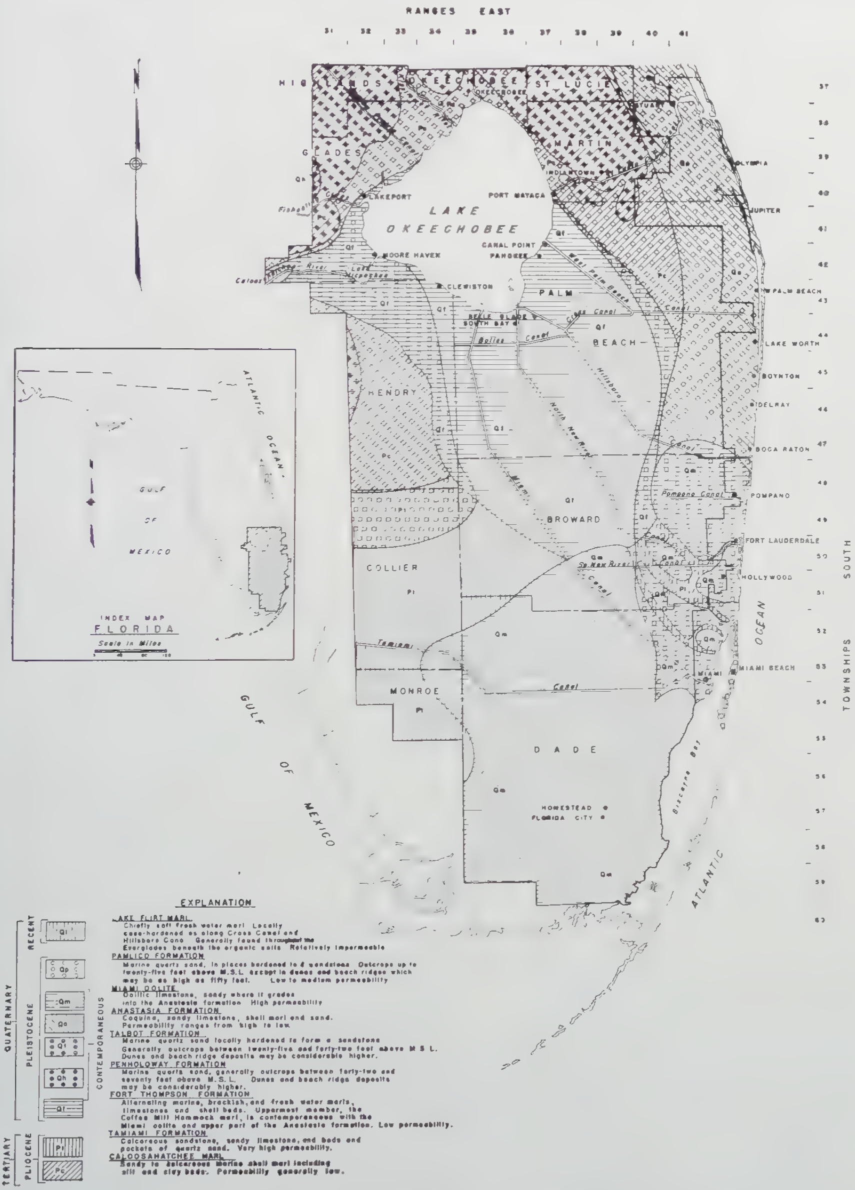

Figure 1.—Geologic map of Everglades Drainage District.

[5] Knopf, Adolph, and others. The age of the earth, National Research Council, Bull. 80, 1931.

mentation in such basins as the Gulf of Mexico off the mouth of the Mississippi, or the Mediterranean off the mouth of the Nile, or the filling of lake basins behind dams. Another method has been based on the recession of Niagara gorge, figuring an average rate of recession per year and dividing the length of its gorge by this rate, thus establishing approximately the date of the withdrawal of the great glaciers which allowed Niagara River to come into being. Still another method has been that of counting the varves (annual silt and mud layers) in glacial lakes to estimate the amount of time since the great glaciers started their withdrawal. These varves in a glacial lake are to the lake much as the annual growth rings are to the tree. From the annual rings the age of the tree can be determined and the climate during the growth of the tree can be told; comparable data can be gathered by a study of varves. Based on such methods, we get the following approximate dates for times in which the rocks of southern Florida were laid down: [6]

Era	Period	Epoch	Duration in millions of years	Time since beginning of each epoch in millions of years
Cenozoic	Quaternary	Recent		
		Pleistocene	2	2
	Tertiary	Pliocene	15	17
		Miocene	20	37
		Oligocene	10	47
		Eocene	13	60

In the immense lengths of geological time many great mountain ranges have been lifted above the sea, only to be eroded away, leaving few traces of their former existence. The seas may invade the continents and stay for a million years or so, then withdraw again. Climates change with the shifting of oceans upon or off the continents; or with the lowering of barriers, such as the Isthmus of Panama, to the movement of great ocean currents; or with the occurrence of clouds of sun spots that cut down radiation from the sun; or with changes in the atmospheric constituents, such as carbon dioxide and water vapor which have great capacity for storage of heat, and which, in sufficient amounts, act as a thermal blanket for the earth.

THE GREAT GLACIAL AGE.—At the close of the Pliocene epoch a great change took place in the earth's climate, a change that brought about the growth of great continental glaciers, which covered about one-third of the northern hemisphere. In North America these glaciers pushed down from dispersal centers in Canada until they covered the northern third of the United States, extending south to a line roughly stretching from Long Island, N. Y., through Cairo, Illinois, to the southern tip of Puget Sound in western Washington. In Europe they covered Scandanavia and Scotland, and reached across the Baltic Sea into northern Germany.

The ice was tremendously thick, being estimated to have had an average thickness of about a mile; it overrode the highest mountain peaks

[6] Hotchkiss, W. O. The story of a billion years, 1932, p. 55.

in New England, gouging the rocks and filling the hollows. It stripped a large part of Canada down to bedrock, and deposited much of Canada's rich soil in north-central United States.

Nor was this the only glacial age during Pleistocene time; in fact, it was the first of four major ones (Table 1) separated from each other by warm intervals comparable to the one in which we are now living. As a matter of fact, it is entirely possible that our Recent epoch should not have that rank at all, rather it should be regarded as another one of the interglacial ages of the Pleistocene. Certainly large masses of ice on a continental scale still exist, such as the Greenland sheet, the Antarctic sheet, and the Arctic sheet.

The causes of the waxing and waning of the great ice sheets are not definitely known. Possibly they are due to a combination of the factors previously enumerated, but the fact of their existence cannot be doubted. Their distribution of rocks foreign to the region where they are now found, their terminal and ground moraines, their gouging of deep lake basins, their rearrangement of stream pattern, and many other evidences are excellent proof of their existence.

The Pleistocene epoch has been divided into four major glacial stages and a minor one, separated by three major interglacial stages and a minor one. The following table, based on that prepared by Parker and Cooke,[7] indicates these stages and deposits of southern Florida which may be correlated with them:

GENERAL EFFECT OF GLACIAL CONTROL OF SEA LEVEL

The sea level fell during glacial stages because of the huge draft on the ocean waters needed to produce the massive continental glaciers; it rose again as the glaciers melted away during the warm interglacial stages. This fall and rise occurred several times, and the effects were world wide. It is interesting to note that with each succeeding interglacial stage the high-water mark of the ocean was lower. Whether this is due to an enlargement in the capacity of the oceanic basin due to crustal movements in some part of the earth, or to more and more ice remaining locked on land during each subsequent interglacial stage, or both, is not known. However, Cooke,[8] has traced these old horizontal shore lines and sea terraces from New Jersey southward into Florida, has checked their elevations, and finds everywhere that they are level. He therefore concludes that no great movements of land with respect to sea level have taken place in this area since the Pliocene.

EFFECTS OF CHANGING SEA LEVELS IN SOUTHERN FLORIDA

The following correlations of deposits in southern Florida are tentative and are to be regarded as hypothetical only. It has been established by glaciologists, working in the glaciated portion of North America, that there were probably four major glacial stages and three major inter-

[7] Parker, Garald G., and Cooke, C. Wythe. Late Cenozoic Geology of Southern Florida with a Discussion of the Ground Water. Fla. Geol. Survey Bull. 27, 1944, p. 20.

[8] Cooke, C. W. Scenery of Florida. Fla. Geol. Survey Bull. 17, 1939, pp. 33-58.

TABLE 1.—TENTATIVE CORRELATION OF FORMATIONS IN SOUTHERN FLORIDA.

<table>
<tr><th>Epoch</th><th colspan="2">Age</th><th colspan="2">Fort Thompson-Lake Flirt Area</th><th>26-mile Bend in North New River Canal Area</th><th>Southeastern Coastal Area</th></tr>
<tr><td>RECENT</td><td colspan="2"></td><td colspan="2">Solution and erosion. Sand bars, dunes, and old channel fills. Deposition of upper part of Lake Flirt marl and organic soils of Everglades.</td><td>Organic soils of Everglades. Lake Flirt marl, upper part.</td><td>Solution and erosion. Formation of beach ridges, organic soils and marl beds (Lake Flirt marl). Local dunes.</td></tr>
<tr><td rowspan="9">PLEISTOCENE</td><td rowspan="3">Wisconsin glacial</td><td>Late Wisconsin</td><td colspan="2">Solution and erosion. Lake Flirt marl, lower part.</td><td>Solution and erosion. River cuts and fills. Soils. Lake Flirt marl.</td><td>Solution and erosion. Lake Flirt marl, lower part.</td></tr>
<tr><td>Mid-Wisconsin</td><td colspan="2">Pamlico formation.</td><td>Rangia cuneata beds.</td><td>Pamlico formation.</td></tr>
<tr><td>Iowan</td><td colspan="2">Solution and erosion. Black carbonaceous sands.</td><td>Solution and erosion.</td><td>Solution and erosion: especially the deep transverse cuts in Miami oolite.</td></tr>
<tr><td colspan="2">Sangamon inter-glacial</td><td rowspan="5">Fort Thompson formation</td><td>Coffee Mill Hammock marl (marine shell bed).</td><td>Undifferentiated</td><td>Upper part of Anastasia formation, Miami oolite.
Upper part of Key Largo formation.</td></tr>
<tr><td colspan="2">Illinoian glacial</td><td>Highest fresh-water limestone ledge merging into soft fresh-water marl below.</td><td>Hard fresh-water limestone.</td><td>Solution and erosion.</td></tr>
<tr><td colspan="2">Yarmouth inter-glacial</td><td>Marine shell marl, “Pecten horizon”.</td><td>Undifferentiated</td><td>Undifferentiated; possibly lower parts of both Anastasia formation and Key Largo limestone.</td></tr>
<tr><td colspan="2">Kansan glacial</td><td>Lowest fresh-water marl locally indurated making a shelf</td><td>Solution and erosion</td><td>Solution and erosion.</td></tr>
<tr><td colspan="2">Aftonian inter-glacial</td><td>Marine shells (local)</td><td>Undifferentiated</td><td>Undifferentiated. May include lower parts of the Anastasia formation and the Key Largo limestone.</td></tr>
<tr><td colspan="2">Nebraskan glacial</td><td colspan="4">Solution and erosion.</td></tr>
<tr><td>PLIOCENE</td><td colspan="2"></td><td colspan="2">Caloosahatchee marl</td><td>Caloosahatchee marl
Tamiami formation</td><td>Tamiami formation</td></tr>
</table>

glacial stages. These are listed in Table 1. The latest minor stages are possibly only fluctuations within the Wisconsin and have been so listed in this paper. This correlation was first presented by Parker and Cooke.[9]

Nebraskan Glacial Age.—When the sea withdrew at the beginning of Nebraskan time, a flat area existed under the central part of the present

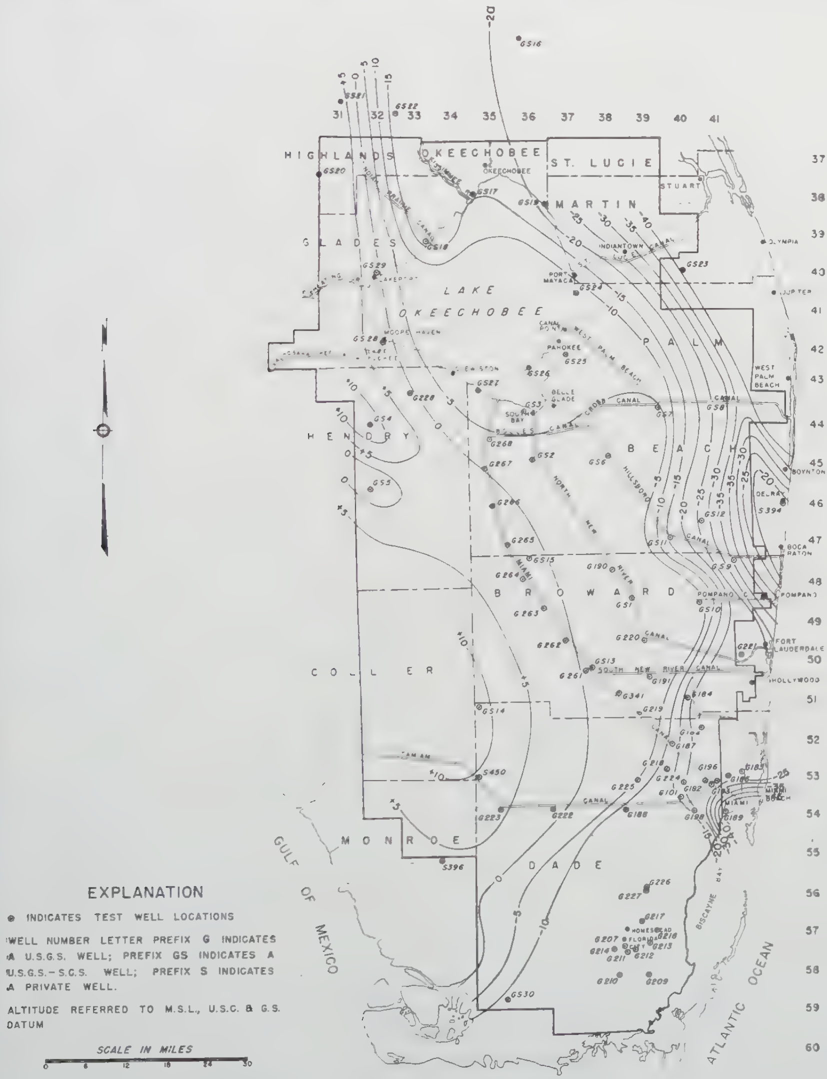

Figure 2.—Map of Everglades Drainage District, showing contours on pliocene surface in upper part of the Everglades, based on test well drillings and location of test wells.

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[9] Parker, Garald G., and Cooke, C. Wythe, *Op. cit.*

Everglades, and higher land lay to the west in the present Big Cypress-Devil's Garden area and to the north about in the latitude of Lake Istokpoga. The deposits of the Pliocene sea had been very shelly and sandy in the upper Everglades area, and limy and sandy in the lower Everglades area and along the coast. The Pliocene surface, from this flat area, apparently sloped steeply to the east under the present Atlantic coastal ridge. See Figure 2 which is based on recently drilled test wells.

This area, then, became exposed to the rigors of weathering, and to the attacks of running surface water and percolating ground water. The latter was an especially potent factor because it created a network of solution holes in the Tamiami formation, the Pliocene rock deposit in the southern part of the area, and started the action which, repeated in subsequent glacial stages, has made this unit one of the most productive water yielding formations that the Federal Geological Survey has ever investigated. But the Caloosahatchee marl was little affected. Composed of sandy shell marl, with beds of clay and clayey marl, it was relatively untouched by erosion and solution, though the surface doubtless was locally eroded by streams. Lake Okeechobee had not yet made its appearance, though small lakes may have existed in the flat area.

Aftonian Interglacial Age.—After the close of Nebraskan time, a warm period called the Aftonian interglacial age ensued, during which the great glaciers melted away, and the sea level rose to about 270 feet above its present level, forming the Brandywine terrace and terrace deposits. Few of the deposits formed in this sea in southern Florida are recognized as such, though they probably existed, and may still be present, included in the "undifferentiated" Pleistocene; most, however, have been stripped away by subsequent erosion. The fact that the sea was fairly deep here at this time, and the sources of sediment far removed, may be another factor in this problem. In the Fort Thompson area, where the entire Pleistocene section is exposed in the Caloosahatchee River banks, the deposits referred to this sea are a few local shell beds, generally preserved only in hollows in the underlying Caloosahatchee marl, and often mixed with the overlying fresh-water deposit.

This invasion by the sea in the Aftonian age may have helped to distribute sand southward along the Atlantic coast, thus building up the Pleistocene deposits under the present area of the coastal ridge. It also displaced the fresh water in the Caloosahatchee and Tamiami rocks, saturated them with sea water, and probably partially or completely filled with sand many of the solution holes developed during Nebraskan time.

Kansan Glacial Age.—The Kansan glacial age succeeded the warm Aftonian interval and again the sea fell below its present level. Once again southern Florida became land, with rivers, lakes, trees, grass, and strange animals present. The sand which had been washed southward around the old flat area during Aftonian time formed a low barrier and allowed a large shallow fresh water marsh and lake to exist in the present upper Caloosahatchee River valley. In this marsh fresh water marl accumulated. This marshy area was the first forerunner of Lake Okeechobee, and may have been considerably larger than the present lake. Once again percolating ground water was at work flushing out the salt

water, and it probably was very effective in the more permeable Tamiami rocks. The Caloosahatchee marl may have been flushed of its salt water, but owing to its lower permeability and greater distance from the ocean this may not have been entirely accomplished.

Yarmouth Interglacial Age.—Succeeding the Kansan glacial age was the warm Yarmouth interglacial age during which sea level rose to 215 feet above present sea level, stood there long enough to establish a definite shore line, then fell to 170 feet, where it remained until the end of the age. In the Fort Thompson area the sea laid down a shell marl containing the shells of many scallops (*Pecten sps.*), marine swimming clams. Doubtless this deposit was once much thicker than it now is, but like earlier deposits, it was largely removed by subsequent erosion. In the other areas of southeastern Florida the sand continued to work southward building up the east coast, and enclosed enough of the present Lake Okeechobee-Everglades depression to allow a large, shallow lake and marsh to exist there in the succeeding interglacial age. Rocks of the lower part of both the Anastasia formation and the Key Largo limestone probably were laid down at this time. This invasion by the sea once again filled the rocks with salt water and displaced the fresh water of the preceding age.

Illinoian Glacial Age.—As the climate cooled again, and the Illinoian glaciers advanced, the sea once more withdrew from the land and fell below present ocean level. Land conditions again existed in southern Florida, and once more a wide, shallow lake and marsh existed in the Lake Okeechobee-Everglades depression. A widespread fresh-water limestone and marl deposit was laid down which today is the most easily recognized member of the Fort Thompson formation. Solution and erosion took place on the higher land, and rivers wended their way from this shallow interior lake to the ocean. Once more fresh ground water began displacing the salt water, dissolving the more soluble limy rocks and adding to the already existing solution holes, thus making the Tamiami more permeable.

Sangamon Interglacial Age.—As the Illinoian ice began to melt away the sea rose during the Sangamon interglacial age, to an elevation of 100 feet above present sea level, then fell to 70 feet, and finally to 42 feet, in each instance remaining long enough to produce definite shore lines and terraces at those elevations. The deposits of the Sangamon have been described before [10] and need only to be mentioned here. Along the eastern shore the bar of oolite (Miami oolite) was being built up to the south of Boca Raton; north of this place it was sandy and shelly, and deposits of coquina, sand, and sandy limestone (the Anastasia formation) were laid down. Outside this bar the coral reef that makes up the present Upper Keys was growing (Key Largo limestone) and behind this bar and reef, in the Lake Okeechobee-Everglades depression countless myriads of shells were accumulating which today make up the uppermost member of the Fort Thompson formation (the Coffee Mill Hammock marl). Salt water again gained access to the rocks, displaced the fresh water, and sand worked into the solution holes developed in the past.

[10] Parker, Garald G., and Cooke, C. Wythe, *Op. cit.*

The deposits of this stage gave southern Florida approximately its modern appearance by building up the higher lands north, west, and east of the Lake Okeechobee-Everglades depression.

Wisconsin Glacial Age and Sub-Ages.—Following Sangamon time the Wisconsin glacial age occurred, consisting of early (Iowan) and late glacial sub-ages, and an intermediate interglacial sub-age. The results were about as follows: In the Iowan or first glacial sub-age, solution and erosion were common on the higher land, and from the lakes that existed in the interior cuts were made through low spots and tidal channels in the newly formed coastal ridge, especially through the soft oolite between Miami and Fort Lauderdale. Fresh water began to flush out the salt water left from the Sangamon invasion, but the time was short, and it may not have progressed very far.

Then during the mid-Wisconsin interglacial sub-age there followed a time of warm weather, the ocean rose to 25 feet above present sea level, and remained long enough to produce the Pamlico terrace and formation which, in southern Florida, is mainly quartz sand locally hardened into sandstone. This is the sand which mantles the coastal ridges as far south as Coral Gables, often completely filling the channels cut through the oolite during the previous glacial sub-age. On the west of the Everglades this sand mantles the Pliocene higher land that underlies the Big Cypress-Devil's Garden area, and to the north it surrounds the higher terraces and generally encloses Lake Okeechobee except on the south and southeastern sides where the wide expanse of the Everglades meets the lake shore. Except where it occurs in beach ridge deposits and dunes inland from the old shoreline, the Pamlico sand is found in altitudes up to 25 feet above M.S.L. Very little of the Pamlico sand found its way out into the present basin of the Everglades proper because the longshore currents that carried it south were not effective in the quieter water of this great shoal area. Again salt water displaced the fresh ground water, and much sand worked its way down into solution holes.

This was the last stand of the sea over southern Florida, but its marks are very evident today. The old bars and current-marked sand deposits are still noticeable, and only partially are being obliterated by surficial drainage, and then mainly in the vicinity of streams where a dendritic drainage pattern is being imposed on the parallel pattern of old beach ridges, off-shore bars, and intervening lagoons that mark some areas in the sandy flat lands in southern Florida, especially in St. Lucie and Martin Counties.

This parallel arrangement is most noticeable from the air and shows very plainly on the aerial photographs made for the Soil Conservation Service in 1940. The trend of the bars and swales parallels the present Atlantic shore line and is entirely confined to the sand land, and does not affect the surficial drainage in the organic soils of the Everglades where, from aerial photographs, one may see a similar arrangement of the drainage pattern. This latter pattern is entirely confined to the peat and muck soils, and has nothing to do with the underlying floor of the Everglades (Figure 3).

Following the warm mid-Wisconsin interglacial sub-age came a short

period of readvance of the northern ice sheet, and sea level fell to about 25 feet below its present stand. Once more fresh water became dominant over salt water in southern Florida. Again a large shallow lake existed in the Everglades, and it may be at this time that the lower portions of the Lake Flirt marl were deposited. Solution of the calcareous rocks and erosion of channels through the Atlantic Coastal Ridge became active once again, and quite likely the re-excavation of former channels that had been choked with Pamlico sand was furthered. Fresh ground water

Figure 3.—Map of Everglades Drainage District, showing directions of surficial drainage.

started displacing the new salt water body, left especially in the Lake Okeechobee-Everglades depression, and may have rather effectively cleared the Tamiami rocks of their salt water.

During this stage of lowered sea level it is likely that the sand dunes along the coast started growing, and they may have attained much of their present size during the waning days of the late Wisconsin glacial sub-age.

Recent.—The beginning of Recent time was marked by the start of the final withdrawal of Wisconsin ice that was brought about by our modern warm climate. The melting back of the great continental ice sheets partially refilled the lowered ocean, and sea level gradually rose to its modern level, drowning the mouths and channels of the short Florida east coast rivers, and making estuaries of the larger ones, of which the St. Lucie is a good example. The rivers on the west coast are longer and larger, so that when their lower courses were flooded they made larger estuaries and better harbors than did those of the east coast. Charlotte Harbor, the drowned mouth of Peace Creek and Miakka River, is a good example of the west coast estuaries.

Along with this rise in sea level came a slowing down of drainage from the interior and a rise in water table. Sand was worked southward along the coast and formed the present beaches, bars, and off-shore spits, and in many places partially filled and choked the old tidal channels through the coastal ridge, which, at least partially, had been re-excavated by late Wisconsin streams. Occasional hurricanes accompanied by huge storm waves and exceedingly high flood tides, redistributed the sand and helped choke the old drainage ways from the Lake Okeechobee-Everglades depression. The result of this blocking of drainage and rise of the water table was the development in the Everglades basin of the valuable marl, peat and muck soils. A great shallow marsh and lake area came into existence, probably extending from near LaBelle on the west to the coastal ridge on the east, and from Okeechobee City on the north to the eastern segment of the North New River Canal on the south. It was very swampy and shallow in the southern part, but was deeper to the north (20 ± feet) where the present greatest depths of this basin are about at sea level. Its principal drainage outlets were through the Atlantic coastal ridge between Miami and Ft. Lauderdale. The first deposits in this basin appear to have been the widespread Lake Flirt marl, a soft, sticky, gray-white, calcereous mud, rich with the remains of certain fresh-water fossils such as *Ameria* and *Planorbis*. This marl, as indicated by field studies, was mainly deposited when the shallow waters evaporated seasonally and the dissolved minerals of the water, principally calcium carbonate, were deposited. This seasonal disappearance of the shallow water brought about the death of myriads of snails whose shells, upon disintegrating, added to the total of $CaCO_3$ considerably. Probably the activity of certain algae and plants caused a considerable amount of the deposition. At any rate, it is widespread in the Everglades, reaching a maximum thickness of about 5 or 6 feet in the old Lake Flirt basin.

In the deeper parts of the area, where the water table always remained above ground, plants became incorporated in the gradually growing

mass of organic material as they died and sank below the water surface, until finally the peat and muck soils of today were developed. As this deposit accumulated and the basin became more and more nearly filled, some of the higher of the old tidal channels across the coastal ridge came into use and modern natural drainage became effective. Short streams such as the Miami River, Arch Creek, New River, and many others came to have their modern form. Thus the surface waters in the Everglades, slowly moving more or less as a sheet in high-water times, and very, very slowly in shallow channels in low-water times, came to move toward these outlets. As they moved, the waters imposed on the soft organic soils and flotant masses a linearly arranged drainage pattern. Trees chose the higher of the areas between the "swales," and the "bays" or "tree-islands" began to take form. Sawgrass or more aquatic plants chose the swales, and the result is the pattern which, as Dickerson [11] says, "reveals a decided 'grain' to a broad sweep of country . . . as if a great coarse broom had been rudely brushed over the low-lying Everglades region." Dickerson postulated ocean currents as the reason for this drainage pattern, but he had interpreted the pattern from the aerial photographs and had not made actual studies of the phenomenon in the field.

The map, Figure 3, is based largely on the aerial photos, and indicates the bar and swale topography (unbroken parallel lines) and the direction of movement of surface water (arrows) as determined from field observations, study of topographic maps, and study of the pattern of individual water courses as shown on the aerial maps. The numbered rectangles enclosed in broken lines indicate the areas shown in the corresponding aerial index photo sheets. The double-headed arrows paralleling the southwestern shore indicate the string of tidal lakes and salt-water runs at the rear of the Ten Thousand Islands.

TEST WELL DRILLING

The fifteen GS [12] exploratory test wells were drilled in critical areas of the Everglades and adjacent lands as indicated on the map. (See Tables A and B, which give location and other data on these wells.)

The wells were of four-inch diameter, and were usually drilled to a depth of about fifty feet, though one was ninety-seven feet deep and one only twenty feet. A standard cable tool rig was used to drill the first eleven wells, but the last four were drilled in areas of deep muck or water where light portable equipment was needed. This was jointly designed by John C. Stephens of the Soil Conservation Service, and John B. Hurst of the Hurst Drilling and Equipment Company of Miami, and was built by the latter. The equipment, built to handle either cable-tools or jetting line and bit, was efficient in all but one respect—if the bit became stuck in the hole the rig lacked efficient means of jerking it out. Fortunately, this sticking of the bit occurred only at one well site.

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[11] Dickerson, R. E. Trend of Pleistocene ocean currents across the Florida Everglades, Geog., Rev., Vol. 32, No. 1, 1942, p. 136-139.

[12] GS is a symbol denoting exploratory test wells jointly installed by the Federal Geological Survey and the Soil Conservation Service.

The test wells were drilled in such a manner that the bit was closely followed by the casing, thus shutting off the upper rock and water which had been passed through, and assuring the collection of valid samples for any given depth. Samples of the cuttings were collected every few feet, stored in quart containers, and taken to the laboratory for study. Water samples were collected as often as practicable, though sometimes the formations were essentially without recoverable water and no sample could be obtained.

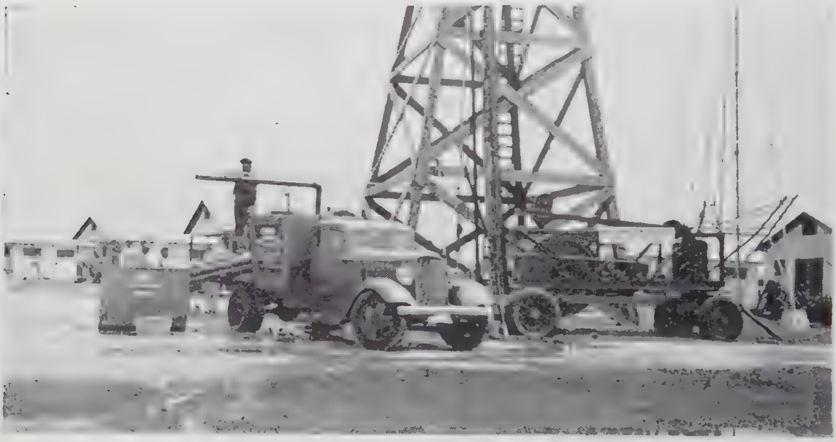

Figure 4.—Pumping test during construction of an exploratory test well (GS-3) near Bean City, Florida. The pump is sitting on the bed of the truck, and discharge is into a volumetric box used to determine rate of pumpage. The standard cable-tool rig used to drill most of the GS wells is in the background.

Figure 5.—Drilling exploratory test well GS-12 on Well Island in the Hillsborough Lakes Marsh in the Everglades southwest of Delray, Florida. The drilling and camping equipment is all portable and was hauled in on airboats.

In drilling wells it is necessary to have enough water in the materials that the cuttings are kept immersed all the time. This makes for easier removal of the cuttings, speeds up drilling, and when the hole is nearly full of water prevents "heave" of the soft, unconsolidated materials by

Figure 6.—Close-up of the portable rig in operation (GS-13). A two-cylinder LeRoi motor turns the "bull wheel" by direct belt drive. A "cat-head" on the shaft is used to grip several coils of the rope line used to raise the bit or bailer. By slackening the coils of rope the bit or bailer falls by gravity. Two men can operate this rig, and can load it or unload it when it is dismantled.

Figure 7.—An airboat used to haul men and equipment over the grassy or weedy waters of parts of the Everglades. These airboats are flat-bottomed, draw very little water, and are powered by a motor with a pusher-type airplane propellor. It is guided like an airplane by a rudder working in the propellor blast. Site is southwest of Delray, Florida, at the edge of the Hillsborough Lakes Marsh.

maintaining equal hydrostatic pressure within the hole and without. Often, however, the formations, especially the Fort Thompson and Caloosahatchee, lacked enough water to supply the well with sufficient drilling water, and it was necessary to add surface water. Before collecting a water sample, therefore, it was necessary to bail all this added water

Figure 8.—Typical view of the upper Devil's Garden area near GS-5. This gives an idea of the transportation difficulties that beset the crew in getting to some of the well sites.

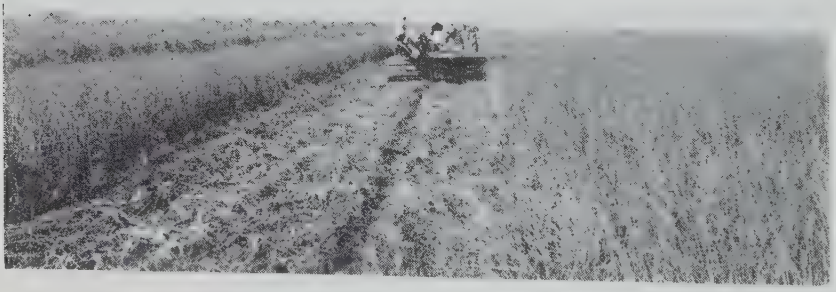

Figure 9.—Typical view of the central part of the Everglades near the 26-mile Bend in the North New River Canal, showing the crew going out to drill GS-15. The big Soil Conservation Service Caterpillar 50 has cleats five feet long bolted to the treads in order to obtain greater bearing surface. It worked very satisfactorily on the soft organic soils.

out so as to be sure of collecting a sample that truly represented the ground water at that depth. Sometimes it required several hours or even overnight in order for enough water to seep in to be used for sampling purposes. All water samples were collected in 12-ounce bottles and were taken to the laboratory for chemical analysis.

Wherever possible, pumping tests were conducted to determine the yield and drawdown, and to note any change in quality of water that might come about through pumping (due to drawing in of deeper water). A 500 gpm capacity Jaeger pump, which could be throttled down to about 20 gpm, was used whenever possible, and was then set to pump the maximum that the well would yield. Whenever the yield was too low to use this pump, a hand-operated pitcher pump, capable of delivering 15 to 20 gpm, was used. Close watch was held on the drawdown, and frequent measurements were made of the quantity of pumped water, and when an equilibrium between drawdown and yield was reached, with the yield the maximum that the well would produce, the test was terminated. Sometimes this equilibrium was reached in 10 or 15 minutes, other times it took as long as an hour and a half. (See Table B of Appendix, which lists data derived from test well drilling and pumping.)

This procedure was the same as had been used previously by the Federal Geological Survey, while gathering data on their many test wells, and was found to be quite satisfactory. From the collected data could be determined the age of the formation so that it could be correlated with rocks in other areas; the hydrologic characteristics could be determined roughly, that is, whether the permeability was of low, average or high order; and the quality of the water present at any given depth could be determined. This latter fact also has considerable bearing in judging the permeability of the formation because it had been noted in southern Florida that, as a rule, wherever the yield is high and drawdown low (high permeability) the quality of water is generally good because the salt water has been flushed out by fresh water; but where the yield is low and drawdown high (low permeability) waters of high mineralization are likely to be found. This rule is not immutable, but even seeming exceptions to it may actually be in conformity. For example, in test well GS-11, at -50.2 feet, it was possible to pump 75 gpm with a drawdown of 2.45 feet, and the chloride was 3,400 ppm. This is not a high permeability, in fact, it is less than average for aquifers in south Florida, but nevertheless a fair yield and low drawdown. This yield is probably from the most permeable rocks in that particular area, and is likely from a lenticular or "shoestring" section surrounded by rocks of very low permeability, otherwise the highly mineralized waters should have been flushed out long ago.

CHARACTERISTICS OF THE FORMATIONS

LAKE FLIRT MARL.—The Lake Flirt marl is a late Wisconsin and Recent deposit consisting principally of soft gray marl or calcareous mud which is locally cemented to make a hard fresh-water limestone. Locally the marl lenses out into peat or muck. Usually it is less than two feet thick, but in the Lake Flirt basin may be as much as six feet

thick. It was named and described by Sellards[13] who gave as its type locality the basin of old Lake Flirt which lies between Fort Thompson and the Atlantic Coast Line Railroad bridge at Goodno. The lake has been emptied by drainage operations.

Recent work has indicated that the marl of the Lake Flirt area is of the same type and origin as the widespread marl which commonly overlies the rocks that compose the floor of the Everglades and fills solution holes in it, therefore the name is hereby applied to all of the fresh-water marl deposits in the Everglades and the coastal marshes of southern Florida. For an account of its origin see p. 44, this paper.

Generally it is a soft, gray, calcareous mud, and as such it is practically impermeable, preventing ground water from percolating through it either laterally or vertically. However, it is not universally present throughout the Everglades, having either not been deposited in these places or having been removed by solution and erosion, and where it is missing the organic soils rest directly on the underlying rock.

In a fairly large area in northwestern Palm Beach County near Lake Okeechobee, the Lake Flirt marl is consolidated into a hard fresh-water limestone, and may be seen on spoil banks of borrow ditches and canals of the area. It is relatively thin there, however, and is penetrated by numerous solution holes so that water may move through it, though not very freely.

In the lower parts of the Everglades, in the area south of the 20-mile Bend in the North New River Canal, the marl is thin or may be missing entirely in some places. In the area of deeper muck in the upper Everglades it is almost universally present.

Pamlico Formation.—The Pamlico formation in Florida was recently differentiated from the Anastasia formation and reported on in a paper by Parker and Cooke.[14] The Pamlico is generally a white to gray quartz sand varying in grade size from very fine to coarse, averaging medium. It contains more or less organic material near the Everglades, and in some places is a black carbonaceous sand due to either an organic stain on the surface of the sand grains or to admixed carbonaceous material, or both. Where the sand is washed clean by rains, and lies higher than the organic deposits of the Everglades, as on parts of the Atlantic Coastal Ridge, it is a dazzling white. In some places the sand contains enough calcareous material to cement it to a sandstone.

Its water-bearing characteristics vary with its make-up. In areas where the sorting is good, and grains are more or less of one size, the permeability is fairly high; in places where the sorting is poor the permeability is low. The admixture of muck with the sand lowers the permeability, and this commonly occurs in a strip bordering the Everglades, or where tongues of Everglades soils cross the Atlantic Coastal Ridge in the transverse glades. Most of the citrus groves in the Davie area are developed on sands of the Pamlico formation.

Wells can be developed in these sands by the use of sand points or gravel packs but the yield is not so high, and the drawdown is much

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[13] Sellards, E. H. Geologic section across the Everglades. Fla. Geol. Surv. 12th Ann. Rep't., 1919, p. 73-74.

[14] Parker, Garald G., and Cooke, C. Wythe. *Op. cit.*, pp. 74-75.

greater than in wells developed in the permeable rocks of the Coastal Ridge.

FORT THOMPSON FORMATION.—The alternating fresh water, brackish, and marine types of limestone, marl, and shell beds that make up this formation take their name from their type locality, old Fort Thompson on the Caloosahatchee River, about 2 miles east of LaBelle.

The area underlain by this formation includes almost all of the Everglades as far south as the 20-mile Bend in the North New River, but the rocks are comparatively thin. Of all the exploratory test wells drilled in this area only one well, GS-11, showed rocks of this age of a thickness greater than 16 feet, and the average thickness is more nearly 10 feet.

For all its thinness, however, it is a very important formation to reckon with in development of the lands in the Everglades. Generally its rocks are of such low permeability that the fresh rain water, which has fallen here since the sea withdrew at the close of Wisconsin time, and the fresh surface waters pouring into the area from Kissimmee River, Fisheating Creek, and other minor streams, have not yet been able to flush the formation completely and fill it with soft water. Toward the southern periphery of its extent the formation carries ground water normal for southern Florida (chloride of 20 ppm or less). In some places around Lake Okeechobee, where the rocks are a bit more permeable than others nearby, some wells yield good water; but the ground water is likely to be high in chloride, sulphate, and bicarbonate, a result of the alternate invasions and withdrawals of the sea in this area, together with the various flushings, more or less successful, and the chemical reactions that have taken place between these waters (so often diluted then reconcentrated) and the enclosing rocks.

In a previous paper by Parker [15] the geologic map showed the Fort Thompson formation extending to the vicinity of the Tamiami Trail. This correlation of Fort Thompson rocks was made on the basis of the occurrence between there and the 20-mile Bend in the North New River Canal of a thin fresh-water limestone above the Miami oolite. Since then field work has indicated that this Tamiami Trail exposure, as well as others above the oolite in the area, is not of Fort Thompson age but of Lake Flirt age, and so should be correlated with this latter formation. The geologic map, Figure 1, accompanying this paper shows the relationship of the various formations as now understood.

The fact that the Fort Thompson is relatively low in permeability makes it a valuable asset in areas of diking and ditching for water control. Water generally percolates through the rocks of this formation very slowly and makes feasible water control in an area having a sufficient thickness of these rocks underlying it. (See Part II of this paper.)

The relations of the various formations, one to another are idealized in Figure 10, which is a typical cross-section of the first fifteen feet below land surface in the middle of the Everglades. This section is based on test-well drilling (GS-15 and 15A) and on an excavation made through the peat into the upper foot of rock. Although the water table at the time of testing stood only about one foot below the land surface, another

[15] Parker, Garald G. Geology and Ground Water of the Everglades. Soil Sci. Soc. of Fla. Proc. Vol. IV-A. 1942.

pit, about 5 feet square and 3 feet deep, could be kept dry by idly bailing with a pint can. This illustrates very well the slow rate of percolation through the peat or upward through the thin marl which overlies the Fort Thompson rocks there.

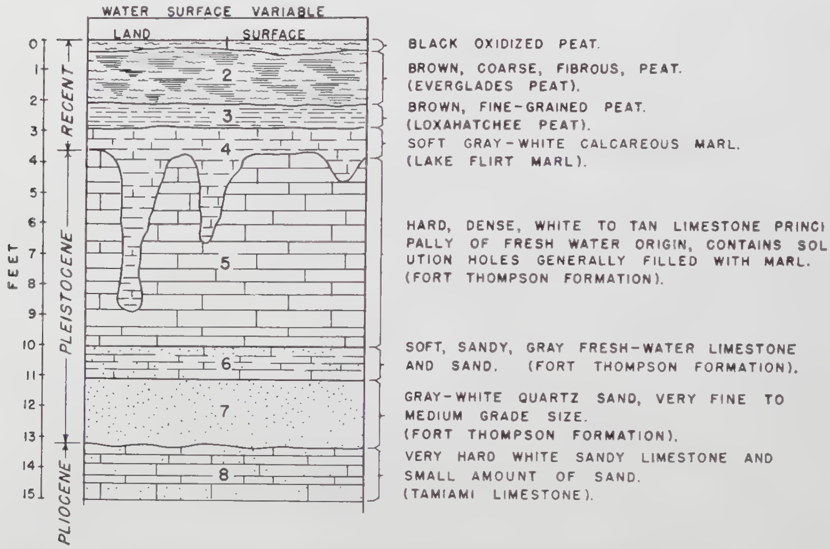

Figure 10.—Typical geological section through soils and rocks of the upper 15 feet in the central Everglades.

Miami Oolite.—The oolite has a limited extent in the Everglades, and is commonly so thin in the interior as to have little appreciable effect on water control. As it is traced eastward from its inner boundary in the lower Everglades it increases in thickness, but at the same time, the Everglades give way to the sandy flatlands and Coastal Ridge. If the oolite is traced south or southwest from the inner boundary it is found to be practically at the surface or only thinly overlain by marl and peaty soils.

It is much more permeable than the Fort Thompson formation, however, and carries potable ground water that is easily pumped.

Anastasia Formation.—Like the Miami oolite, the Anastasia has a limited extent in the Everglades. It underlies the Atlantic coastal ridge north of Boca Raton, and extends westward slightly beyond the eastern margin of the Everglades, where it merges with at least the upper two marine members of the Fort Thompson formation.

It is quite sandy and shelly, and in places consists of a sandy limestone or calcareous sandstone, or coquina, and as such is generally a permeable formation. The sand content, however, keeps it from being so highly permeable that control of the water table would be difficult, and in places the sand is so poorly sorted that permeability is quite low.

Ground water in the Anastasia is generally potable and is usually obtained in wells finished with a sand screen, though where enough sandstone or limestone is present unscreened wells may be developed.

Caloosahatchee Marl.—This formation is generally a sandy shell marl, but contains local layers or beds of clay, clayey marl, clayey sandy marl, sandy limestone, or lenses of pure sand. The rocks grade laterally or interfinger laterally with those of the Tamiami formation, though the Tamiami in its youngest phase overlaps the Caloosahatchee, especially in the Big Cypress Swamp area. This latter relationship led Parker,[16] to believe that all the Tamiami was younger than the Caloosahatchee, and his cross-sections shown in that paper indicate that interpretation, but later investigation indicates that the Tamiami and the Caloosahatchee are contemporaneous.[17]

The Caloosahatchee marl, because of its large amount of very fine sediments and very poor sorting (small particles filling spaces between larger ones) is generally of rather low permeability. This is indicated by both microscopic and macroscopic studies of the sediments, by laboratory permeability tests, by pumping tests conducted during the work on the exploratory test wells, and by the highly mineralized waters that are so commonly found in these rocks. Were the formation very permeable fresh ground water should long ago have flushed the mineralized water out.

This feature of the occurrence of highly mineralized waters in both the Caloosahatchee and Fort Thompson formations was first reported by Stringfield,[18] who conducted a reconnaissance survey of the area immediately surrounding Lake Okeechobee, then later was treated by Parker,[19] who reported on the drilling of test wells in the Everglades.

In general, the Caloosahatchee is buried too deeply to be of much actual importance to land usage; however, its low permeability which prohibits the use of drainage wells, and which, with the general poor quality of water its rocks contain, limits the development of supply wells, is of prime importance to those who might wish to gain a living on land underlain by this formation.

Tamiami Formation.—This formation, except in those areas where it is highly sandy, is among the most permeable ever investigated by the Federal Geological Survey, and ranks with clean, well-sorted gravel in its ability to transmit water. The permeability is greatly reduced in the sandy portions, however, and approaches the low transmissibility of the Caloosahatchee. The highly permeable area in general underlies the Atlantic Coastal Ridge, having a thickness of over 75 feet in the vicinity of Miami's well field, and it becomes thicker seaward. Inland it thins out, contains more sand, and becomes less permeable where it interfingers with, or grades into, the Caloosahatchee marl. Even so, a considerable area of the lower Everglades is underlain by this highly permeable aquifer.

The Miami oolite thinly overlies the Tamiami wherever the oolite is present in the Everglades, and in places the contact of the two formations may be seen in rocks dredged from the shallow drainage canals.

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[16] Parker, Garald G. *Op. cit.*, p. 65.

[17] Parker, Garald G., and Cooke, C. Wythe. *Op. cit.*, p. 64.

[18] Stringfield, V. T. Ground Water in the Lake Okeechobee Area, Florida. Fla. State Bd. of Conservation, Rep't of Investigation No. 2, 1933.

[19] Parker, Garald G. *Op. cit.* p. 62; also Tables 2 and 3.

In extreme low water the contact is visible in many places along the South New River Canal west of State Highway 26.

In general, land situated over the Tamiami rocks would be highly unsuited to water control structures installed for farming purposes. Ditches, dikes, dams, and pumps would be of little avail because of the exceedingly high permeability of the rocks beneath. In winter, when water would be needed it could not be held by dikes, and in summer when excess water would need to be pumped off it could not be done because the water table could not be lowered sufficiently by pumping. (See Part II for complete treatment of this phase of the subject.)

SUMMARY

The rocks that underlie the Everglades are comparatively very young, most of them having been formed during the several oscillations of sea level that took place during the Pleistocene, or great ice age. Starting on a fairly flat Pliocene sea bottom various marine, brackish, and fresh-water deposits were laid down; marine deposits when the sea covered the area; fresh water deposits when the sea had withdrawn entirely, and brackish water deposits in times when embayed areas contained a mixture of fresh and salt water.

Longshore currents sweeping down the Floridian shore line swept huge quantities of sand from the north, especially along the Atlantic shore, even as they are doing today, and finally built up the sea platform so that, along with some of the limy deposits in the south which were being deposited at the same time, the edges of the Floridian Plateau became slightly higher than the interior, and in this shallow depression the present Everglades and Lake Okeechobee were formed.

Erosion and solution, too, had a profound effect in southern Florida. Some of the earliest of the deposits have been almost entirely removed and only small remnants of these former deposits are preserved in hollows or solution holes in older formations. Solution has opened up solid limestone or calcareous sandstone beds by riddling them with holes made by percolating ground water, thus making for high permeability which allows wells to yield copious supplies of water with small drawdown.

Of the formations having a direct effect on land utilization in this area, the most important are the Caloosahatchee marl, the Tamiami formation, the Fort Thompson formation, the Miami oolite, the Anastasia formation, the Pamlico formation, and the Lake Flirt marl.

The Caloosahatchee and Fort Thompson formations generally have a rather low order of permeability and in most instances, whether overlain by Lake Flirt marl or not, the water table above can be controlled by adequate diking, ditching, and pumping. These formations, too, are likely to contain salty ground water high in sulphate and bicarbonate.

The Miami oolite and Tamiami formation, however, offer serious hazards to those attempting water table control in areas underlain by these formations because their rocks are generally so permeable that in the dry season water could not be maintained in diked areas much higher than normal, and in the rainy season ground water inflow would maintain a high water table even during heavy pumping. These formations, being

open and permeable, have been flushed of their sea water and now contain potable ground water.

The Anastasia formation underlies only a small part of the Everglades. It generally contains enough fine sand to permit the control of water levels in soils overlying it.

The Pamlico formation is typified by the sandy farm land near Deerfield, Pompano, Fort Lauderdale, and Davie. Permeability in these sands varies considerably from place to place, but usually is not too high to permit of adequate water table control.

The Lake Flirt marl is of considerable importance since it is practically an impermeable layer which usually overlies the rocks and underlies the organic soils in the Everglades. Where it is present under sufficient thickness of soil that ditches do not cut through it, the water table can be controlled even in areas of permeable underlying rocks.

Full treatment of the engineering aspects of water control and its relation to the rocks of the Everglades is discussed in Part II of this paper.

CHAIRMAN MOSSBARGER:

Thank you Mr. Parker for a fascinating presentation of a difficult subject. We will now see how Mr. J. C. Stephens, Associate Drainage Engineer with the Soil Conservation Service in Fort Lauderdale, proposes to put these findings to work in a practical way to assist with the job of soil and water conservation in the Everglades. Mr. Stephens.

Part II

The Relationship of Sub-Surface Hydrology to Water Control and Land Use in the Everglades

JOHN C. STEPHENS [1]

"Geology stands to engineering in the same relation as faith to works . . . the success or failure of an undertaking depends largely upon the physical conditions which fall within the province of geology, and the 'works' of the engineer should be based on the 'faith' of the geologist." Boyd Dawkins, F. R. S.[2]

The following is Part II of a progress report on sub-surface investigations made during 1942 in the Everglades of Florida by the Soil Conservation Service in cooperation with the United States Geological Survey. Part I of the report by Messrs. Garald G. Parker and Nevin D. Hoy of U. S. Geological Survey, covers the details of the procedure and methods used in the investigation, the outline and map of the areal geology, the effects of glacial control of sea levels on the geology, and the description and general hydraulic characteristics of the formations encountered. Part II will attempt to explain, from the engineering viewpoint, the application of the results of these investigations to water-control and land-utilization problems of the area. After a brief, general review of the reclamation and conservation problems of the Everglades, the application of these findings to the problems will be discussed.

It should be borne in mind that the studies are not completed, and that conclusions stated herein are, therefore, only tentative. The Everglades Drainage District is about the size of the State of Massachusetts, and only a limited number of drillings were made. Additional test wells are to be drilled, and further data collected concerning seepage into the canals, and concerning movement of water through the soil and through the rock.

THE PROBLEM

Agricultural development in the Everglades must proceed in accordance with a rational plan of water-control if the potentialities of the area are to be realized. The trend of development must follow a definite pattern in accord with the capability of the different lands within the area, and water-control plans based on sound engineering principles must be carried out. Water control in the Everglades involves drainage of those portions where and when an excess of water interferes with best use of the lands, and irrigation of those portions where and when a lack of water interferes with best use of them. In cropped land the ground water table should be maintained at the highest elevation that will permit good crop growth, in order that subsidence of the ground surface by oxidation and by fires may be held to the minimum. In non-agricultural

[1] Associate Drainage Engineer, U. S. Department of Agriculture. Soil Conservation Service, Ft. Lauderdale, Fla. (See also Proceedings Vol. IV-A, p. 24, 1942.)

[2] Leggett, R. F. Geology and Engineering, Page 61, McGraw-Hill Book Co., Inc., New York, 1st Ed. 1939.

areas the water table should be held at or above ground surface to prevent subsidence by oxidation or burning. In areas devoted to wild life, the requirements for that purpose should be observed. In all areas, as large a portion of the water should be conserved as possible consistent with the designated major use of the land and health considerations, to supply water needed for irrigation in dry periods and to furnish domestic and municipal supplies for people and cities in and bordering the Everglades.

The original drainage plans for the Everglades were based on the assumption that practically the entire body of organic soils was capable of supporting profitable agriculture. This assumption showed a lack of knowledge of the nature of the Everglades and a lack of appreciation of the problems to be encountered in the development of the area. The value of the better lands in the Everglades is proven by the millions of dollars worth of agricultural produce grown annually during the winter season when most other agricultural regions of the country are dormant. The potentialities of the area have not yet been realized, and the present area in cultivation is less than a third of the area which is believed capable of supporting a profitable agriculture. Although the value of the better lands is unquestioned, surveys show that there are vast acreages which are of no value for agriculture, and experience has shown that attempts to farm these submarginal areas are detrimental to the more valuable lands. Experience also has shown that even the more valuable soils of deep peat may be destroyed by fires and oxidation. This loss of soil by subsidence takes place whenever the water is taken off, and is greatly accelerated by overdrainage. Thus, the use of peat soils predicated on drainage is a form of exploitation, just as surely as coal mining is exploitation, since once utilized, neither can be replaced within the ordinary life span of a nation.

The analogy of farming the peat soils of the Everglades and the mining of coal may be carried even further. Numbers of good coal veins have been ruined by "peckerwood" miners who endeavored to mine the coal without a coordinated plan. Usually, each miner followed a different scheme, and headings, galleries, and rooms ran helter-skelter in every direction. Soon after the easy-to-mine out-crop coal had been mined out, and before the heart of the coal could be extracted, the miners often found that others, who had followed different schemes of development, blocked their way. Consequently, cave-ins occurred, and only a small fraction of the potential value of the coal vein was realized, which resulted in a loss to both the miners and the community.

The present development in the Everglades bears a grave similarity to this wasteful method of mining. At present, the cultivated acreage in the Everglades is being rapidly expanded without a practical water-control plan for the whole area. The present drainage system is hardly adequate for the area now in cultivation, and a rapid expansion of the farm lands without regard to outlets or to land capabilities will soon result in conflicting systems of water control. Even now adjacent farms compete for the same over-taxed outlets, and units with the weaker dikes or levees may be flooded.

Compare this, on the other hand, with the results of a carefully planned and coodinated mining enterprise. First, surveys are made to

determine the extent of the deposit. The quality of the coal is examanied and analyzed, bearing in mind its potential use. Bore-holes are drilled to determine which areas are valuable enough to warrant extraction, and which are thin and have poor coal that should be left as pillars to support the roof. In other words a complete survey or inventory is made of all the factors which determine the value of the seam. After a careful study of these surveys, a plan is made for systematic extraction of the coal. As a result, the coal is taken out with a minimum of loss—a gain for both miners and the community.

So it should be with the development of the Everglades. Without a plan and policy based on surveys and investigations, only a part of the potential value of the area can be realized. Therefore the most important requirement for the area is the adoption of a plan to bring about the orderly development of agriculture, according to a definite pattern which will provide water-control for all lands. The solution of this problem involves engineering questions of water-control based on proper consideration of the physical factors of the area, including the geology, the soils, the topography, and the location with respect to roads, as well as other economic factors.

RELATION OF GEOLOGY TO GROUND WATER

Evidently it is imperative that an over-all water-control system be set up in the Everglades. Since it appears equally evident that the success of the system will depend on a thorough knowledge of the technical factors involved, the general relationship of geology to ground water will be examined.

Meinzer [3] has shown that the hydrology of the ground water is everywhere controlled by the geology. In some instances the rain falls on open, porous formations and seeps beneath the surface, where it is only loosely held by the rocks, and almost immediately flows out through the rocks and soils into streams or canals quickly enough to augment flood peaks and make the task of flood control and land drainage difficult. Sometimes the rain seeps into tighter rocks, is held longer, and furnishes a steady source of flow for the streams during dry periods—the so-called base-flow. Or, under favorable conditions of geological structure, some of the rainfall seeps down deep through the rocks and finds its way into artesian channels from whence it may come back to the surface of the land, or even discharge underneath the sea, hundreds of miles away from its starting point. Some of the artesian water travels fairly rapidly and may emerge as good, potable drinking water; other travels very slowly and remains underground foı thousands of years in contact with the rock, where it usually dissolves enough salts from the confining rocks to become too highly mineralized for use by either plants or animals. Apparently some water may be held within the rocks and remain entrapped for millions of years, or even eras of geologic time. Thus the geology of an area is the dominating factor which controls the hydrology of the ground water.

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[3] Meinzer, O. E. Hydrology, Physics of the Earth, IX, 1st Ed., p. 6. McGraw-Hill Book Co., New York, 1942.

Not only do geology and rock structures have a dominating influence on the natural hydrology of the ground water, but the permeability of the rock and its proximity to the ground surface also have a great deal to do with the feasibility of controlling the water table and consequently the best land use.

For instance, the success or failure of water control by means of dikes and pumps is mainly determined by the permeability of the rocks near the surface. Permeability is the measure of the freedom with which water moves through a formation. Highly permeable rocks carry water freely, whereas rocks of low permeability hold the water relatively tightly. Pumping from ditches in permeable rock is like pumping from ditches connected with a system of tile drains extending back for miles on both sides of the ditches. Therefore, when areas of shallow soils where highly permeable rocks lie close to the surface are diked and pumped, the water flows freely under the dikes from surrounding lands at such a high rate that the pumps are unable to control the water table within the area. Conversely, when areas where impermeable rocks underlie the surface are diked and pumped, little ground water flows in, and the pumps can easily control the water table within the enclosed unit.

The influence of rock structure on water control practices is shown also by the flow in the arterial drainage canals. The canals that cut through highly permeable strata drain the adjacent lands to the limit of their ability to remove the water. This may be for miles back during dry times, and only a short distance in wet times. Then during dry seasons, when high water tables may be desirable, it is difficult to maintain them, as the water tends to seep away through the adjoining permeable formations. When control dams are placed in the canals to maintain high stages, it is usually necessary to provide for the inflow of fresh water to offset these seepage losses and the additional water loss by infiltration around the end of the dams.

In contrast, canals through impermeable formations do not drain very far back from their edges, unless laterals are provided. Since there is little seepage loss, such canals are efficient in carrying irrigation water to distant areas, and control structures to maintain high water tables during drought are effective. Experimental levees constructed along the canal banks have been effective in holding back the water, as evidenced by the fact that water stands on the surface of the soil for days in such areas. These levees are also helpful in alleviating flood damage where the storm runoff from undeveloped areas would otherwise flow immediately into the canal and occupy its full capacity when it is needed to remove flood water from lands under cultivation.

SOURCE OF WATER SUPPLY FOR THE EVERGLADES

Two specific questions which the Everglades investigations propose to answer are: (1) What is the source of the water which inundates the Glades; (2) What effect has the regulation of Lake Okeechobee on the inflow of seepage water to the Glades? Methods of controlling water occurring as free ground water coming from local rainfall or nearby surface sources are considerably different from those necessary to control

confined ground water coming from distant sources under artesian pressure. The regulation of the water level in Lake Okeechobee was known to have reduced the amount of overflow during flood periods from the Lake onto the Glades, but it was desired to ascertain if underground flow from the Lake contributes any appreciable amount to the water in the Glades, and what effect controlling the Lake level has on such flow.

The source of water for the Glades has been ascribed by various persons to be everything from ordinary rainfall to upwelling underground rivers and geysers. Passengers on boats which formerly traveled along the North New River Canal were said to have seen jets of water spraying geyser-like above the surrounding sawgrass; and it has been recorded by some of the early explorers that there were "immense springs

Figure 1.—The water table in the Everglades is typically close to or above ground surface. Here a Soil Conservation Service glades tractor is down in a particularly soft area. Sub-surface hydrologic investigations show that most of the water in the Glades comes from local rainfall.

rising from the earth, covering an extent of several acres, and throwing up a large quantity of water with great force, and supplying the Everglades with all the water flowing through them." [4]

To determine whether it is free ground water or confined ground water that exists in the upper rock strata under the Everglades, a small hole or well was put down through the muck to the water table beside each well drilled into the rock.[5] As drilling progressed in the rock and different strata were encountered, measurements were made to determine what difference there might be between the water level in the small

[4] 62nd Congress, 1st session. Senate doc. 89, Everglades of Florida, p. 64.

[5] Described by Parker and Hoy, Part I of this report.

hole and that in the drilled well. There was a difference in only one instance. At well GS-6, on the Brown Farms, within a diked unit where the water table was pumped down below the outside water level and where the water in the nearby Hillsboro Canal was above land surface, a difference was found and water overflowed at a rate of 6.3 gallons per minute from the top of the well casing, which stood 0.13 foot above the land surface. Later, when the water in the Canal was not higher than that on the land, the elevations in the well and the muck hole were the same. The fact that at a majority of these wells the water from the rock always stood at the same level as that in the surface soil indicates that in the upper strata of rock there is no flow of water under pressure from distant locations that contributes appreciably to the water in the Everglades.

Figure 2.—Artesian flow from 2,838 feet below the surface of the Everglades. These waters are first tapped in the Tampa limestones at approximately 400 to 1200 feet depth, and are too highly mineralized for irrigation or domestic use. They are sealed off from the surface by the impermeable Hawthorne formation and do not contribute to the water in the Everglades. (Courtesy of U. S. Geological Survey.)

This conclusion is corroborated by subsequent Soil Conservation Service wells approximately 150 feet deep drilled along the northern shore of Lake Okeechobee, and the deep U. S. Geological Survey wells in the Miami area. These additional wells disclose that the surface rocks in the Glades are underlaid at a depth of from approximately 125 to 200 feet by a dense, impenetrable formation, the Hawthorne, which is 300 to 500 feet thick. All artesian flow from the Highlands area, located above the Glades, appears to be confined to rocks beneath the Hawthorne, some 400 to 1,200 feet below the ground, and are thus sealed off from

the surface water and have no direct effect on agricultural water-control problems.

The typical occurrence of the water table, which is usually close to or above ground surface, is shown by Figure 1, while Figure 2 shows artesian flow tapped by a deep test well drilled by a private concern in prospecting for oil along the Tamiami Trail west of Miami.

Although these studies show that there is no artesian flow contributing to the water of the Glades, the fact that in one well the water from the rock rose higher than the ground water level reduced by pumping reveals an important condition. Evidently, in some parts of the upper Glades, water can move laterally through rock strata more readily than through the surface soil. Under such conditions, drainage ditches cannot cut off or intercept this sub-surface flow, and in certain instances water in a canal at high stages may pass beneath drainage ditches and upwell in the area beyond. It is believed that this lateral movement is not extensive, and is confined to lenses of rock that are only local. Such lenses are probably not interconnected, and usually pinch out within a mile or so. However, there is some indication of such a lens of considerable extent underlying about half of Lake Okeechobee and extending out to the south and east for a short distance. Yet it is believed that underground flow through the rock from Lake Okeechobee is not sufficient to affect general water conditions in the Glades except immediately adjacent to the Lake, where high stages may cause enough seepage to increase pumping requirements.

Evidently the water that inundates the Everglades comes largely from rainfall upon the Glades themselves, except for such as is released into the canals from Lake Okeechobee.

AREA DIVISIONS BASED ON HYDRAULIC CHARACTERISTICS OF THE ROCK

Because of the controlling effect of the permeability of the upper strata of rock on the feasibility of water control, one of the primary purposes of the investigation was to collect information concerning the relative permeability of the rock.

Here, in general, are the results indicated: The upper rock strata in the upper portions of the Everglades are relatively tight and of low permeability, whereas they are more open and much more water-bearing as they approach the eastern and southern rim of the Glades. Furthermore, the relatively impermeable or non-water-bearing rocks of the upper Glades seem to be, for the most part, overlain by the deeper peat soils, while the more permeable rocks in the lower Glades are overlain by shallower peat. This is of course not always true, but the general rule is: Good, deep agricultural peat—tight, relatively impermeable rock; shallow, non-agricultural peat—open, permeable rock.

The division between the loose and tight rocks is not a definite line across the Everglades, having permeable conditions on one side and impermeable conditions on the other. Rock formations in the Glades do not butt smoothly, one against the other, as a carpenter would join two boards; they grade one into the other, in places interfingering in

dovetail fashion. Too, it was found that the permeable formations are in the shape of a wedge, feathering out in the interior of the peninsula and thickening toward the coast.

To complicate the matter further, a rock formation mapped under a given name, the Tamiami for example, rarely has the same hydraulic or water-bearing qualities throughout, because the formation has a wide

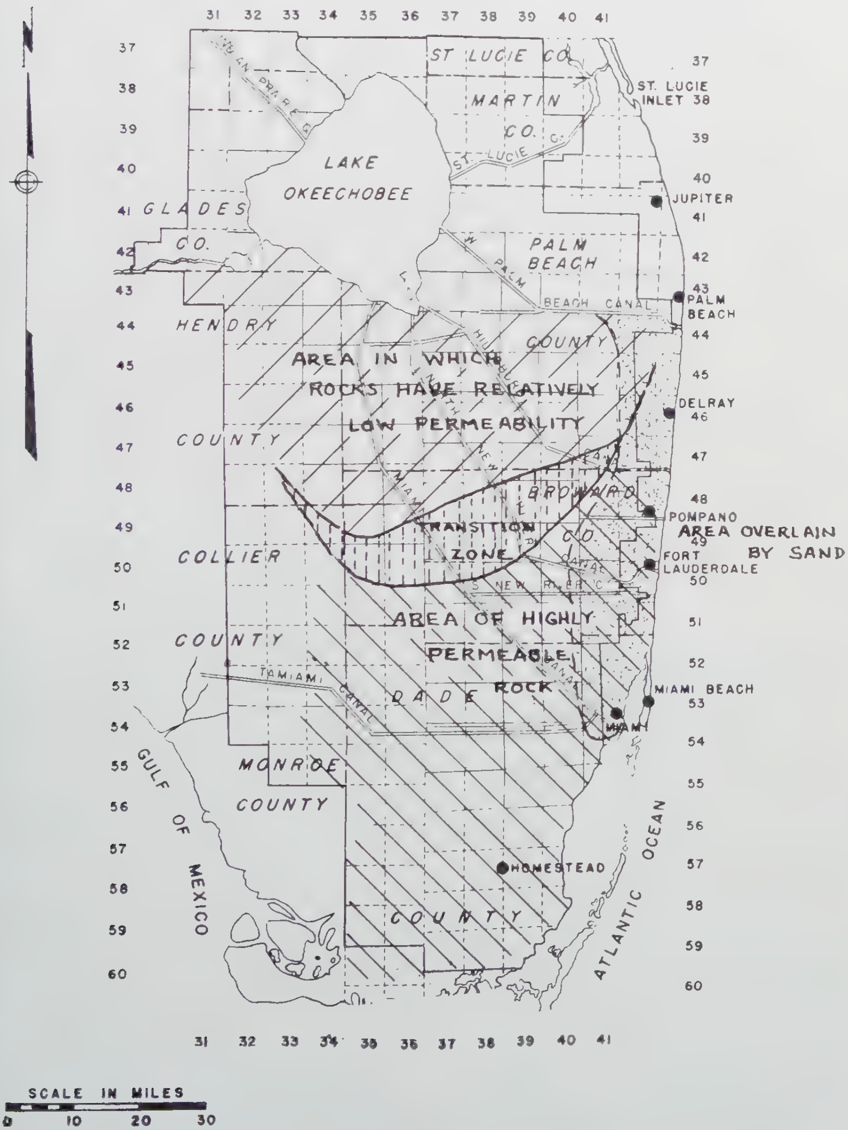

Figure 3.—Map of the Everglades Drainage District, showing location of highly permeable and relatively impermeable rocks underlying the area.

range of characteristics due to differing circumstances of deposition and character of material involved. Thus, the Tamiami, which is usually thought of as the most permeable formation in the area, frequently has a sandy phase of low permeability at the interior edge, and a highly permeable sandy limestone phase toward the outer coastal area, as has been pointed out by Parker and Hoy in Part I.

However, in spite of the difficulties involved, the belt between the loose rock to the south and tight rock to the north may be traced across the Glades as shown by the map, Figure 3, which outlines the area of impermeable rocks in the upper Glades, the transition zone in the middle Glades, and the outer area of permeable rocks in the lower Glades. The division goes about as follows: At the Miami Canal it crosses some 5 or 10 miles above the intersection of the Miami and South New River Canals, and swings northeastward in a curve which crosses the North New River Canal between 26-mile Bend and the Broward-Palm Beach County line; from thence it continues in a northeasterly curve to the Hillsboro Canal, which it crosses between the Range Line Road (Florida 199) and Elbow Bend; then it swings northerly and practically parallels the present coastline. Between the Hillsboro Canal and the West Palm Beach Canal, the surface limestone progressively becomes sandier and tighter, so that the surface rocks along the West Palm Beach Canal are all relatively impermeable. In this area, the permeable rocks evidently plunge downward toward the coast so rapidly and are covered so deeply by the Pamlico sand that they have little influence on control of surface waters.

West of the Miami Canal. the location of the division lines are less well known as only one test well has been drilled in this section of the

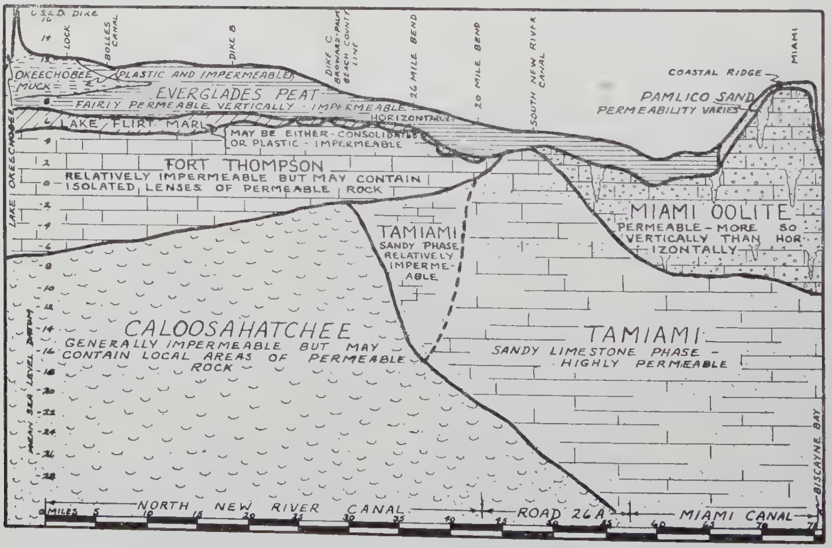

Figure 4.—Generalized, north-south, profile through the Everglades from Lake Okeechobee to Miami, showing relation and relative permeability of upper strata.

Glades. However, from this well and reconnaissance surveys of the areal geology, the divisions are tentatively plotted as shown by the dotted lines in Figure 3.

A generalized north-south profile cross-section of the upper strata through the Everglades from Lake Okeechobee to Biscayne Bay near Miami is shown in Figure 4. A study of this profile, with the relative permeabilities of the rock strata in mind, will indicate the difficulty of obtaining water control by dikes and pumps in the low, shallow, organic soils in the lower Glades, while dikes and pumps have been effective in the upper Glades.

(a) The Upper Glades

In this report, "Upper Glades" refers to the area of deep organic soils north of the transition zone shown on Figure 3, to Lake Okeechobee, Caloosahatchee River, and approximately West Palm Beach Canal.

In peat soils the original compaction and subsidence losses amount to about 2 feet at the end of 10 years of cultivation.[6] This loss in depth, plus the fact that the water level in drainage ditches must be held approximately 2 feet below ground surface in order to secure adequate drainage for most crops, means that there must be a soil depth of at least 5 feet in order to maintain sufficient ditch capacity without deepening the farm drainage ditches into the underlying strata at the end of approximately 10 years. Where the underlying material is rock, expensive to excavate, this 5-foot peat depth is held by drainage engineers to be the minimum that can be successfully developed under present economic conditions.

Practically all of the present agricultural development of organic soils now occurs in the upper Glades where the soils are deep and the rock relatively impermeable. Experience has shown that in this area seepage into the farm drainage ditches is slow and that water control by diking and pumping is practical. Heretofore, the depth of the peat itself was given credit for being the predominant factor in preventing excessive seepage, and relatively little attention was given to the role of the underlying strata because the majority of the ditches do not penetrate the rock. Clayton[7] found verticle seepage through 18 inches of raw, brown, fibrous peat taken at 18 to 36 inches depth to be as much as 27.3 feet of water per day under a pressure head of only 19 inches. From this, it is seen that the undisturbed peat itself has relatively little effect in retarding water from rising vertically through it from underlying sources.

In drilling the test-wells in the Everglades, a layer of marl or sedimentary peat frequently was found between the organic soils and the hard limestone. Wherever this marl occurred, it acted as an almost perfect seal and prevented the water in the rock below from gushing into the bore hole; yet when this marl was perforated, water usually filled the hole rapidly. The author has found by permeameter tests that

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[6] Clayton, B. S., Neller J. R., and Allison, R. V. Water Control in the Peat and Muck Soils of the Florida Everglades. Univ. of Florida Agricultural Expt. Station Bull. 378, Nov. 1942, pp. 15-17.

[7] *Ibid.* Pp. 17-19.

the seepage rate through samples of marl found at the bottom of the peat soils is negligible, even under a pressure head of 48 inches. From this it appears that this stratum is very important in preventing high seepage rates even in the deeper peat soils.

The effectiveness of as little as 2 to 3 inches of marl as an impermeable layer was observed at Well GS-15, some 12 miles west of Florida Road 26 on the Palm Beach-Broward County line. Here a small pit was dug in the peat some 3 feet deep, and the marl was not penetrated. It was easy to keep the water drawn down in the pit by bailing occasionally with an old tomato can. Yet when the nearby 4-inch well hole punctured the marl and penetrated the rock for several feet, 70 gallons of water could be pumped each minute from the pit surrounding the well—a pit differing from the earlier-described one only in the fact that the marl seal was broken and water from the underlying rock allowed to well upward.

Although the tigher rocks of the upper Glades, such as the Fort Thompson formation, are much less permeable than the Tamiami formation or Miami oolite of the lower Glades, they may carry a surprising quantity of water in solution holes occurring in the rocks or in permeable lenses, as already described. As shown in Part I by Parker and Hoy, the Fort Thompson formation is made up of alternating layers of fresh, brackish, and marine deposits which are generally capped over by the Lake Flirt marl. Solution holes which were made in the various rock layers during the past geologic time, when the sea was at low levels, were in turn refilled or covered over by each subsequent deposit. But it is believed the top layer of marl capping these strata, being much younger and also being unexposed to the higher pressure heads caused by lowered sea levels during waxing glacial stages than were the older strata, has not yet had time to develop these solution holes to any appreciable extent, even where the marl has been hardened to rock and the peat apparently lies directly on top of hard rock. Thus, as many farmers have discovered in installing pump foundations, if the seal layer of rock or marl is stripped away, solution holes or relatively permeable layers are sometimes uncovered which allow water to pour into the excavation and make control of the water very difficult.

Figure 5 is a photograph taken during the excavation for a pump foundation in the upper Glades, which illustrates the value of the top rock in sealing off the water. Here the peat lies directly over the consolidated Lake Flirt marl, which is a dark grey hard limestone about 2 feet thick, containing fresh-water fossils. Directly under the Lake Flirt bed is a white limestone of Fort Thompson age, containing marine and brackish-water fossils. Most of the water comes from fissures and holes in the white limestone under the greyish Lake Flirt limestone which acts as a sealing cap.

The question as to whether it will be economically feasible to continue farming in the present developed area around Lake Okeechobee when it becomes necessary to deepen the majority of drainage ditches into the underlying rock is still unanswered. Although it is self-evident that pumping will be increased if the upper rock seal is broken, the feasibility of pumping such increased flow will depend not only on the

Figure 5.—Excavation for a pump foundation in the upper Glades. The peat lies directly upon consolidated Lake Flirt marl, here about 2 feet thick. Immediately beneath this is a white limestone of Fort Thompson age, upon which the level rod rests. Most of the water in the pit comes from fissures and holes in the Fort Thompson limestone.

technical question of whether the solution holes and permeable lenses are sufficiently extensive and interconnected to allow free passage of water, but also on the economic matters of production costs and market prices for agricultural products. There are the further possibilities of improvement in water-control equipment that will reduce the cost of ditching and pumping, and of great strides in the preservation of foods that will increase competition of northern states for Florida's present market for winter crops.

In brief, the sub-surface investigations indicate that, in the Upper Glades, where the peat is of the proper type and exceeds 5 feet in depth, water control is feasible and the lands can be profitably developed for agriculture because of the relatively impermeable nature of the underlying rock and the marl seal. Apparently the unit method of development is feasible, whereby unit areas of moderate size can be reclaimed successively as wanted by diking and pumping, thus allowing the idle land to be preserved under water until needed.

(b) The Lower Glades

The area of shallow organic soils directly underlain by highly permeable rock, shown as the south half of the map, Figure 3, but not including the coastal area of mineral soils and organic soil underlain by sand, is the area herein called the "lower Glades." Parts of this area are underlain by some of the most permeable rocks in the United States. These rocks near the lower east coast have a permeability comparable to that of washed gravel.[8] The high yield and low drawdown from wells in the Miami area which tap the Tamiami formation, and the high rate of seepage inflow measured along canals which cut through the Miami oolite, are evidence of the high permeability of the surface rocks in the lower Glades. For instance, along the lower reaches of the Miami Canal, where the flow is largely seepage from the underground rock reservoir, the rate of seepage into the canal sometimes reaches 100 second-feet, or approximately 65,000,000 gallons a day, per linear mile of canal. Figure 6 shows a ditch cut into the Miami oolite. Figure 7 shows the open, permeable nature of this formation.

Over such highly permeable rocks, it is obviously impracticable to try to control the water table within any given unit by levees or dikes and pumps, because the water flows under the impounding devices. Therefore, it would appear that drainage in the lower Glades must be planned on a regional basis, whereby enough canals of sufficient size would be dug to carry off all the water from the entire area underlain by the highly permeable rocks.

The peat soils in the lower Glades are shallow and subsidence studies show that the life expectancy of these soils when drained is too short to pay the cost of drainage. It is granted that canals could be dug with a capacity sufficient to care for the runoff over a period of a year at reasonable cost. However, it is the intense storm of relatively short duration that growers are primarily concerned about, and the capacity

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[8] Cross, U. S., Love, S. K., Parker, G. G., and Wallace, D. S. Progress Report on the Investigation of Water Resources in Southeastern Florida. Prepared by U. S. Geological Survey, mimeographed report, Dec. 1940. P. 12.

of the canals would have to be sufficient to remove from 2 to 3 inches of rainfall from over the entire area in 24 hours to provide adequate drainage for truck crops. Canals of such size are impractical.

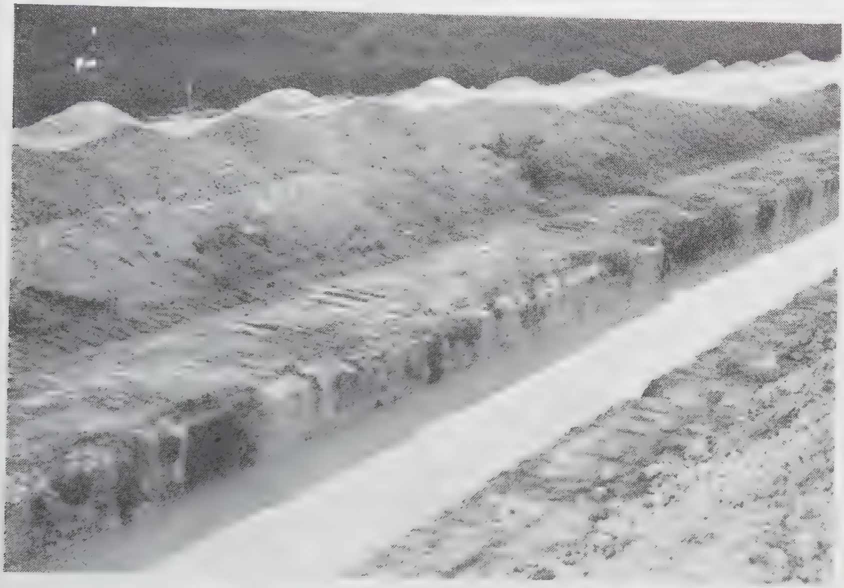

Figure 6. -A drainage ditch through permeable rock in the lower Everglades. Note the porous nature of the rock and the large, dark, soil-filled solution holes. It is not feasible to dike and pump land over this type of rock, as water from outside will flow under the dikes. (Courtesy of U. S. Geological Survey.)

Even if enough funds were expended to dig such canals, it would doubtless be disastrous to adjacent lands and to the water supply along the lower East Coast. U. S. Geological Survey studies indicate that "all of the available information, including the stream flow records, the test-well records, the permeability computations, and the estimates of recharge and discharge point to the conclusion that very large quantities of ground water are available for use in the coastal area." The Miami oolite in the vicinity of Miami is capable of storing and yielding about $1\frac{1}{2}$ gallons of water for each cubic foot of rock. However, "control works to prevent excessive drainage through the canals are necessary before the water-bearing formations will function satisfactorily as a reservoir." [9] The profile, Figure 4, shows that the highly permeable water-bearing rock under the coastal-ridge area of mineral soils extend some 40 miles back under the lower Glades, and Figure 3 shows this open permeable formation to underly the whole southern end of the Everglades Drainage District. The shortest route of drainage canals from the Glades to tide-water would cut through the higher coastal lands, and canal stages low enough to drain the low-lying organic soils would necessarily overdrain the coastal area. Therefore, drainage of the lower

[9] *Ibid.* Pp. 81-85.

Glades is bound to have a detrimental and damaging effect on the more valuable coastal soils, which now are capable of bearing a heavier burden of taxes than the cheap lands when drained. If ill-considered attempts are made to drain this area and exploit the so-called "cheap lands" in the lower Glades by wholesale gravity drainage, it is believed that these efforts will, in effect, "kill the goose that lays the golden eggs."

Furthermore, municipal water supplies located near the ocean are very susceptible to contamination by salt water, which, being heavier than fresh water, is constantly tending to displace the potable water. The

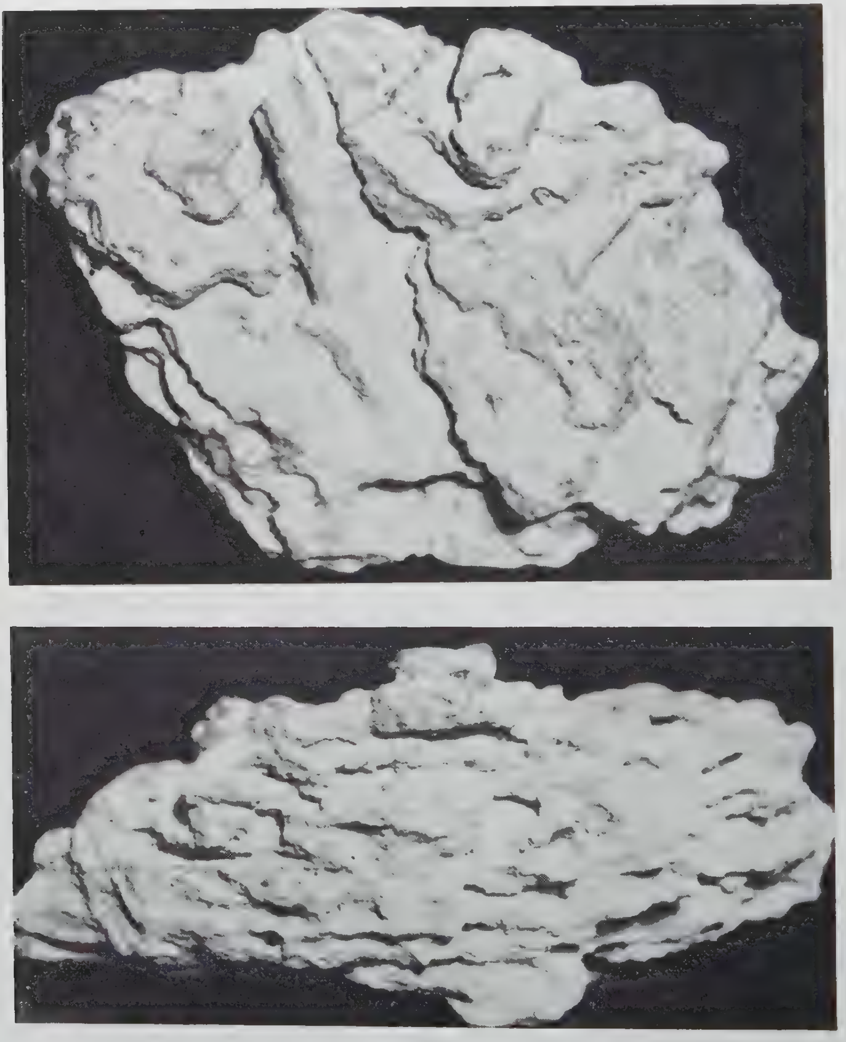

Figure 7.—Top (above) and side views of Miami oolite. If saturated, this rock ordinarily will yield about 1½ gallons of free water per cubic foot. Courtesy Florida Agr. Expt. Station.

danger of such contamination is shown by present conditions in the Miami area where there is an interlacing network of drainage canals flowing freely into the sea. Federal Geological Survey studies show that here the heavier sea water has wedged up the canals under the fresh water, and seeped through the porus rocks and contaminated the underground water supply. Fresh water springs that once flowed freely in the Miami area are now dry—the result of overdrainage. The city's water supply was contaminated in the dry season of 1938-39, was threatened again in 1942, and will become more vulnerable as time goes on if more lands are overdrained. Years ago Thomas Carlyle sounded the warning:

> "Nature keeps silently a most exact Savings Bank and official register correct to the most evanescent item . . . and at the end of the account, you will have it all to pay, My Friend, there's the rub."

From the foregoing discussion it follows that without proper water conservation measures in the lower Glades, which are a part of the intake area where the underground reservoir of highly porous rock is recharged by rainfall, the water stored in these rocks will be unable to supply the amount of non-saline water needed for irrigation and for domestic and municipal purposes. The fresh-water head, in and back of the coastal area, should be maintained as high as feasible to obstruct infiltration and intrusion of the sea water.

The canals that are now being used for irrigation of the coastal lands are wasting considerable amounts of water into the sea; but it appears that if the natural recharge conditions are maintained, wherever the highly permeable Tamiami formation occurs at a reasonable depth and of reasonable thickness, as it does in the vicinity of Miami and Homestead. the water can be obtained more cheaply from wells, pits or collecting galleries than from ditches extending back into the Glades.

In brief, it appears that in the lower Glades, because the highly permeable nature of the underlying rock makes water control very difficult and because the shallow depth of organic soils indicates that they cannot be reclaimed by drainage for agricultural use with profit under present economic conditions, and further because drainage of these lands would have seriously detrimental effects upon the valuable coastal lands, the best use of the lower Glades would be for water storage and wildlife conservation.

QUALITY OF WATER

Whenever samples of the ground water could be obtained during these investigations, the quality of the water was determined. This information was obtained not only for the light it might shed on the theoretical aspects of the geology and the clues it might give on the rock structure itself, as explained by Parker in Part I; but also, because it was desired to delimit, if possible, the areas of highly mineralized ground waters known to exist in the upper Glades which are unfit for irrigation or domestic use. These highly mineralized ground waters seep into the canals, and during the dry season when fresh water inflow, either from rainfall or from Lake Okeechobee, is limited, the water in the arterial canals becomes so highly contaminated that it is unsuited for public supply.

It was thought that if the areas of mineralized waters are only local, it might be possible to route fresh water from Lake Okeechobee around those areas and supply good water to West Palm Beach and adjacent localities directly through canals from the Lake.

The allowable concentration of minerals for irrigation water in South Florida is not known. Scofield, in reporting on investigations in Southern California regarding the allowable concentration of minerals for irrigation water, stated that the critical concentration for chlorides was 142 to 325 parts per million.[10] However, it is believed that the allowable critical concentration of minerals in irrigation water for South Florida is higher, because the water is only used during the dry season to augment any deficiency in rainfall. The total annual rainfall for the area is from 50 to 60 inches; therefore it seems probable that the rainfall that occurs during the irrigation season will dilute the concentration of salts, and that heavy rainfall which occurs during the wet summer months will flush out the salts in the soil and prevent any accumulation from year to year. Nevertheless, crops have been ruined by irrigating them with mineraized ground water in the Everglades. The value of knowing the location of these mineralized waters in planning any development or water-control program is self-evident.

From analyses made by the Federal Geological Survey of the water obtained from the test wells and from previous analyses from other wells,[11] the Everglades can be divided, on the basis of the quality of the ground water, into two areas which roughly coincide with the areas of relatively impermeable rock in the upper Glades and permeable rocks in the lower Glades, as shown by Figure 3. The rocks of low permeability in the upper Glades contained water of poor quality, often too highly mineralized for either domestic or irrigation purposes. On the other hand, the more permeable rock in the lower Glades contained uncontaminated, potable water.

As explained in Part I, there appears to be a definite relation between the permeability of the rock and the quality of the groundwater. Apparently the "poison water" in the upper Glades is water that has been in the rocks of low permeability since the various sea invasions of the Everglades, caused by the waxing and waning of the glaciers, and has had no chance to escape; while the ground water in the permeable rocks of the lower Glades is comparatively fresh rainwater which has flushed out and replaced the ancient sea water. Furthermore, the water in the tight rocks probably remained entrapped for such long periods that it dissolved out additional minerals from the enclosing rocks, while the water moves so rapidly through the open rock that it has little opportunity to dissolve the minerals.

The quality of ground water in the upper Glades, although generally quite poor, varied so from place to place that the areas of highly mineralized water could not be delimited by the test wells. In some places potable water is found below the surface, while a well drilled a short

[10] South Coastal Basin Investigation—Quality of Irrigation Waters. Calif. Dept. Pub. Works Bull. 40, 1933.

[11] See Appendix B herein, and Garald G. Parker in Soil Science Society of Florida, Proceedings Vol. IV-A (1942). Pp. 73-76.

distance away will tap salty water. Frequently in this area wells which supply potable water when first drilled become salty after use. There are indications of an isolated area of fairly permeable rocks underlying about half of Lake Okeechobee and the land immediately adjacent to the south and east, which contains a stagnant body of highly mineralized water containing as much as 4,000 to 5,000 parts per million of total dissolved solids. The chloride content runs as high as 1,500 and the sulphate as high as 500 parts per million. The water is believed to be stagnant and isolated because otherwise such concentration of the minerals would have been diluted and flushed out.

ELECTRICAL RESISTIVITY TESTS FOR DETERMINING SUB-SURFACE CONDITIONS

Inasmuch as the character of the ground water in the upper Glades was found to be too spotty to make the use of test wells feasible in mapping its quality, it was decided to experiment with an electrical resistivity method for this purpose. Since laboratory tests showed that the conductivity of the water varies almost in direct proportion to the amount of soluble salts it contains and the well studies showed that the mineral content of the ground water is closely correlated with the rock permeability, it was reasoned that it might prove possible, by measuring directly the resistance of the underlying material to an electrical current, to determine by this means certain geologic facts such as differences in rock structure, especially between highly permeable and impermeable strata, and where excessively highly mineralized bodies of ground water occur.

Accordingly, the resistivity experiments were made in 1943 in cooperation with the Public Roads Administration, which loaned the equipment and an operator for the trial study. Figure 8 shows the equipment used in making the tests.

The general procedure consisted of making resistivity measurements down to a depth of 100 feet at previously drilled test well sites where the well logs were available and the underground conditions known. The resistivity curves obtained from these depth tests were then plotted alongside the well log data, and correlations attempted between the well logs and resistivity curves.

Although final judgment of the value of the method must be withheld pending additional work, a preliminary analysis of the data indicates that the use of the resistivity outfit in the hands of an experienced operator may have merit in the Everglades area for determining underground conditions. The resistivity of the formations investigated were found to range from 1,000 to 1,500 ohmcentimeters for the muck and underlying formations in the vicinity of the southern part of Lake Okeechobee to more than 20,000 ohmcentimeters for the oolitic limestone and Tamiami formation found in the vicinity of the City of Miami. This wide range in resistivity suggests the possibility of determining, within reasonable accuracy, the zones within which the several materials are predominant. From the rather limited tests, it appears that both Miami oolite and Tamiami formations can probably be identified by reason of their rela-

tively high resistivity characteristic. The Fort Thompson formation apparently has an intermediate resistivity which, nevertheless, can be differentiated from that of the highly permeable oolite and the Tamiami formation. The Caloosahatchee marl lying beneath the above-mentioned rock formation is quite impermeable and has a relatively low resistivity, and its presence can often be predicted by data obtained by resistivity measurements. Although there may be areas near the coast where a particular contamination of chloride waters may cause a hard rock formation to appear as a marl, a reasonable knowledge of geological conditions usually offers sufficient control to prevent error in interpretation. It appears that appreciable amounts of dissolved minerals lower the resistivity of the materials in which they are incorporated; therefore,

Figure 8.—Making a resistivity test. This type of test measures the resistance of the underlying material to the conductance of an electrical current, and may, thereby, give clues on certain geologic conditions and indicate the quality of the ground water.

when the typical resistivity curve for a geologic section is known beforehand. the presence of dissolved minerals in solution will be indicated by a subdued resistivity apparent in the curve. A special series of tests made from north to south at 2-mile intervals through the Everglades to determine how the resistivity trend concurred with the geologic profile showed a definite trend from a rather high resistivity in the highly resistant rocks at the southern end of the Glades to a lower resistivity characteristic of the surface and sub-surface material in the vicinity of Lake Okeechobee. Further work with this method of test will more firmly establish the economic value of the resistivity test in studying the water-quality problems peculiar to the Everglades.

SUMMARY

The hydrology of the ground water is everywhere influenced by the geology. The head and movement of the water, its quantity and quality, are all controlled by the structure and material of the rock formations. Some of the rainfall passing beneath the surface is only temporarily stored, and flows through the upper rock and soil fast enough to augment flood flows in the streams and seriously interfere with the handling of surface runoff by the canals. Some of the water may sink deeper, and furnish the principal flow of the streams during dry seasons; some may seep even deeper, into artesian channels, and return to the surface or the sea thousands of years later; and apparently some has remained trapped in tight, deep formations through millions of years.

In view of the important interdependence between geology, water-control, and economic development of land in the Everglades, the Soil Conservation Service has, as part of the Everglades Project, undertaken a careful investigation of the subsurface hydrology in the area in order to properly evaluate the effect of geology upon the planning of an overall and rational program of water control for the Glades. In 1942 studies were made in cooperation with the Federal Geological Survey and other agencies by means of 15 test wells to determine subsurface structure and quality of water, and by means of seepage flow rates into canals. Preliminary studies were also made to determine the feasibility of electrical resistivity tests to explore subsurface conditions. The results, briefly summarized, are as follows:

The wells showed no evidence of artesian or pressure flow in the upper rock strata, from which the water rose only to normal ground water level. All pressure flow is confined to artesian channels some 400 to 1,200 feet below the ground surface, and has no effect on agricultural development. The deep artesian waters, at least as far north as Lake Okeechobee, are in fact unpotable and unsuited for either domestic or agricultural use. There is no substantial subsurface flow in the Glades from the Lake except in limited areas immediately adjacent to the Lake's edge. The effects of Lake regulation on the water table at any considerable distance are negligible. The source of the water in the Everglades is mainly local rainfall.

In general, the upper 50 feet of rock strata in the central portion of the Everglades are relatively tight and non-water-bearing, whereas they become looser and highly water-bearing as they approach the eastern

and southern rim of the Glades. Consequently the chances of being able to control the water table are normally good in the inland area, but become less and less toward the outer fringe of the peat soils.

The marl layer frequently found between the hard rock and the organic soil is an effective seal against the water in the rocks. The Fort Thompson rocks, while relatively non-water-bearing compared to the Tamiami or the Miami oolite, are made up of alternating layers deposited by the shifting sea levels. Solution holes are frequently found in the rock formed during periods of lowered sea levels and in turn refilled or covered over by subsequent deposits. These holes frequently carry an abundance of water. If the sealing layer of rock or marl is stripped away, these solution holes are sometimes uncovered and water control is extremely difficult, even in the upper Glades where the rocks are relatively tight. It appears that, where the soil is of the proper type, the best land use of the upper Glades will be for agriculture.

For the most part, the highly water-bearing rocks thicken toward and extend under the eastern coastal area of mineral soils. Without proper water-conservation measures in the lower Glades it will be difficult to maintain the quality and quantity of water needed for irrigating the more valuable agricultural lands along the coast, and for supplying the municipalities in that section. It appears also that ill-considered attempts to exploit the "cheap lands" in the lower Glades will have detrimental effects upon more valuable neighboring areas. Apparently the best use for much of the land in the lower Glades will be for water storage and wildlife.

The ground waters in the upper Glades are often highly mineralized, and in places are unsuited for either domestic or irrigation use. However, waters in the highly water-bearing rocks in the lower Glades are usually sweet and potable.

Geophysical experiments indicate that the use of the resistivity outfit in the hands of an experienced operator may have merit in the Everglades area for determining underground conditions, particularly when used in conjunction with test wells.

There is a need for additional studies, which are already planned, to extend our knowledge of the best water-control and land-use practices in the Everglades as determined by the subsurface hydrology and other physical characteristics of the area.

Chairman Mossbarger:

Thank you Mr. Stephens for your illuminating statement of the close working relationship between the character of the underlying rock strata and the quality and amount of the waters they contain in comparison with waters in and on the land.

We will now listen to a report by Mr. M. H. Gallatin, Assistant Soil Technologist with the Soil Conservation Service on the progress that has been made on the soil survey of the Everglades area which, we were told last year, has been under way since early 1940. Mr. Gallatin.

APPENDIX

TABLE A.—Location, Depth, and Diameter of GS Test Wells.

Well No.	Location	Started	Finished	Depth (feet)	Diameter (inches)
GS-1	Glades 72′ west of middle of Fla. 26 and 190′ south of southern end of bridge at the 26 Mile Bend on Highway (Fla.) 26	6-2-42	6-4-42	55.3	4
GS-2	Off shoulder of road between North New River Canal and Fla. 26. Well is 3.5 miles south of Bolles Canal and 30.5′ from middle of Fla. 26.	6-5-42	6-9-42	50.0	4
GS-3	3 miles west of South Bay and 1 mile south of Fla. 25 at the water tower of the South Shore Camp of the U. S. Sugar Corp.	6-9-42	6-12-42	50.0	4
GS-4	Located between the Devil's Garden Road and an abandoned borrow pit 3.6 miles south of Fla. 25.	6-15-42	6-16-42	50.0	4
GS-5	Located on east shoulder of Devil's Garden Road 13.8 miles south of Fla. 25.	6-17-42	6-17-42	50.0	4
GS-6	Located in turn-out of Fla. 198 7.2 miles south of Fla. 25 bridge over Hillsboro Canal.	6-18-42	6-23-42	55.0	4
GS-7	Located on southeastern side of Fla. 25 at east end of bend that is 0.5 mile southwest of intersection of Fla. 194 and Fla. 25.	6-24-42	6-25-42	50.0	4
GS-8	Located 51 feet north of center line of Fla. 25 at a point 0.35 mile west of intersection of Fla. 25 and Fla. 199.	6-29-42	6-30-42	51.0	4
GS-9	Located 60 feet west of middle of Fla. 199 and 230 feet south of bridge over Hillsboro Canal.	7-1-42	7-2-42	52.0	4
GS-10	Located 5.9 miles westerly from Fla. 149 near Hammondsville, or 3.0 miles westerly from Bud Lyons' farm buildings, and on south side of Pompano (Cypress Creek) Canal.	7-6-42	7-7-42	50.0	4

TABLE A.—LOCATION, DEPTH, AND DIAMETER OF GS TEST WELLS—(Continued).

Well No.	Location	Started	Finished	Depth (feet)	Diameter (inches)
GS-11	Located on S. C. S. road on south side of Hillsboro Canal 11.0 miles west of Fla. 199.	8-3-42	8-7-42	96.7	4
GS-12	Located on Well Island in the Big Lakes country about 6 miles west of Fla. 199 and 4 miles north of Hillsboro Canal.	8-13-42	8-14-42	50.2	4
GS-13	Located on northeast side of Miami Canal on spoil bank at end of deeply excavated portion of canal (¼ mile northwest of confluence of Miami and South New River Canals).	8-25-42	9-4-42	50.0	4
GS-14	Located on Johnny Pool's Island (also known as Two Palms Island) about 15 miles (?) north of Tamiami Trail in Everglades near margin of Big Cypress Swamp.	9-24-42	9-26-42	51.0	4
GS-15	Located in Broward County almost on Palm Beach-Broward County east-west boundary, and 11 + miles west of Fla. 26.	1-11-43	1-18-43	18.3	4
GS-15A	Located about 10 feet southwest of GS 15	1-19-43	1-19-43	20.0	4

* See also map, Figure 2, page 39.

Quantity and Quality of Water Available at Different Levels in the GS (1-15) Series of Test Wells as Associated with the Profile Characteristics of Each. (Correlations and Analyses by the U. S. Geological Survey).

TEST WELL No. GS-1

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-1	Black oxidized peat.	Recent 1	Practically impermeable.	118	Water sample from N.N.R.C. 6-2-42, 4:40 p.m. Heavy rains started. 75°
1-2	Hard calcareous sandstone; dark to light gray color. Fresh water origin.	Fort Thompson	Very low permeability.	107	W.S. from N.N.R.C. 6-3-42; 11:15 a.m. Heavy rains continued. 74°
			Very low permeability.	74	W.S. from N.N.R.C. 6-4-42; 4:35 p.m. 76°. Heavy rains continued
2-12.5	Sandy shell marl, consolidated in places to a shelly calcareous sandstone.	12.5		90	6-2-42; 4:10 p.m.; —5.5′; 75°
12.5-14	Shelly quartz sand.	Tamiami (sand)	Permeable. At — 14′ pumped 35 min. at 39 gpm with drawdown of 5.24′.	36	6-3-42; 11:15 a.m.; —14′; 74°. Pitcher pumped.
14-23.5	White quartz sand, very fine to fine.		Low permeability. Had difficulty getting enough water for a sample.	37	6-3-42; 12:50 p.m.; —14′; 74°, after pumping test.
		23.5		38	6-3-42; 2:35 p.m.; —23.5′; 75°
23.5-39.9	White quartz sand, very fine to medium. Fossiliferous.	Caloosahatchee	Small amount of water available, some places not enough for drilling purposes. Low permeability.	60	6-3-42; 4:50 p.m.; —33.3′; 75°
				61	6-3-42; 5:32 p.m.; —36.4′; 75°
				79	6-3-42; 6:40 p.m.; —39.9′; 76°
				79	6-3-42; 7:40 p.m.; —44′; 76°
39.9-55.3	Shell marl ranging from light to dark gray. Contains very fine to fine quartz sand.		Scarcely enough water for water samples. Very low permeability.	202	6-4-42; 9:25 a.m.; —51.4′; 76°
				248	6-4-42; 10:15 a.m.; —55.′; 76°
				190*	6-4-42; 10:35 a.m.; —55.3′; 76°

* Probably contaminated by surface water added for drilling purposes.

Test Well No. GS-2

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-6.8	Muck and peat.	Recent 6.8	Low permeability.	6	W.S. from N.N.R. Canal 6-5-42, 10:15 a.m. 77°
				5	W.S. from N.N.R. Canal 6-8-42; 3:00 p.m. 80°
				7	W.S. from N.N.R. Canal 6-9-42; 11:05 a.m. 81°
6.8-16.5	Hard, shelly calcareous sandstone with a mixture of both marine and fresh water fossils. Mixing probably done in drilling. Extremely hard limestone layer between —11.6′ and —12.5′.	Fort Thompson	At —11.6′ pumped 45 min. at 12 gpm with a drawdown of 10.2′. Low permeability.	25	6-5-42; 11:45 a.m.; —11.6′ L.S.; 75°, after pumping.
		16.5	At —16.5′ pumped 30 min. at 16 gpm with a drawdown of 8.58′. Low permeability.	35	6-5-42; 2:15 p.m.; —16.5′ L.S.; 75°, after pumping.
16.5-30.4	Shell marl, poorly consolidated in places to a friable shelly sandstone.		Very little water. Could bail hole dry easily. Very low permeability.	112	6-8-42; 12:20 p.m.; —22.7′; 76°
				118	6-8-42; 1:30 p.m.; —23.6′; 76°
				115	6-8-42; 2:50 p.m.; —30.4′; 76°
30.4-36.5	Sand and shells, probably a sandy shell marl.		Very low permeability.	172	6-8-42; 3:05 p.m.; —33.8′; 76°
				192	6-9-42; 9:20 a.m.; —36.5′; 75°
36.5-38.2	Hard shelly sandstone.	Caloosahatchee	Permeable, but due to thinness not a lot of water is available.	180	6-9-42; 10:35 a.m.; —38.2′; 76°
38.2-49	Shell marl, sandy in places, and contains thin streaks where the marl is consolidated into hard rock.		Practically no water available.	190	6-9-42; 11:45 a.m.; —41.7′; 76°
				188	6-9-42; 1:45 p.m.; —46.8′; 76°
49-50	Very fine quartz sand.		Low permeability.	195	6-9-42; 2:05 p.m.; —50′; 76°

Test Well No. GS-3

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-7.4	Muck and peat. Noted no marl.	Recent 7.4	Low permeability. High cl. due to contamination by irrigation water from nearby well.	75	From pit dug in muck 17′ N. of GS-3. 6-11-42; 2:45 p.m.; —3′; 78°
7.4-23.5	Sandy shell marl with hard flinty layers and some soft chalky white limestone. Shells mainly brackish and marine types though some fresh water fossils are present. Apparently alternating thin beds of these types of deposits.	Fort Thompson	Generally low permeability. At —18.9′ pumped for 25 min. at 99 gpm with drawdown of 3.81′. Permeable for a few feet here.	49	6-11-42; 10:25 a.m.; 18.9′; 75° H_2S odor.
				45	6-11-42; 11:27 a.m.; —18.9′; 75°. H_2S odor. After pumping.
		23.5		61	6-11-42; 12:30 p.m.; —23.5′; 76°. H_2S odor.
23.5-34.6	Shell marl, sandy, gray to dark gray. Has a few thin streaks of hard rock —32′ to —33′.		Very low permeability.	83	6-11-42; 1:00 p.m.; —29.2′; 76°. H_2S odor.
				133	6-11-42; 2:45 p.m.; —34.6′; 76°. Water has foul odor.
34.6-36	Hard limestone layer containing sand and shells.	Caloosahatchee	Dense. Carries little water.	122	6-11-42; 3:35 p.m.; —35.5′; 80°. Temperature is high due to sun-heated bit.
				144	6-11-42; 3:50 p.m.; —36′; 77°. H_2S odor.
36-50	Shell marl containing very fine sand.		Very low permeability. Difficult to obtain enough water for samples.	147	6-11-42; 4:15 p.m.; —40.5′; 77° H_2S odor.
				146	6-11-42; 5:00 p.m.; —46.5′; 77°. H_2S odor.
				165	6-11-42; 5:15 p.m.; —50′; 77°

Test Well No. GS-4

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-6	Sand and few shells.	Pamlico 6	Well using sand point could be made down to 10′ but yield would be low.	10	From borrow pit 8′ deep near well. 6-16-42; 10:00 a.m.; 85°
6-13.8	Soft, friable, calcareous sandstone with much sand contained in its meshwork of solution holes.	Fort Thompson 13.8	Permeable to —10′. Little water below that.	24	6-16-42; 9:30 a.m.; —138′; 76°
13.8-23.1	Creamy tan to brown quartz sand.		Not enough water available for a sample. Very low permeability.	23	6-16-42; 10:25 a.m.; —19.1′; 76°
23.1-39	Gray to grayish white quartz sand.	Caloosahatchee	Very low permeability.	40	6-16-42; 2:00 p.m.; —39′; 81°. Temperature of water raised by sun-heated bit and bailer.
39-50	White quartz sand, very fine to coarse but so poorly sorted as to have small grains filling interstices between larger ones.		Very low permeability. Bailed well dry and let stand for 60 min. Sand heaved in 25′ but enough water was available for a sample.	59	6-16-42; 5:30 p.m.; —50′; 79°. Temperature high due to sun-heated bit and bailer.

TEST WELL NO. GS-5

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-10	Carbonaceous sand, dark brown.	Pamlico 10	Very low permeability.	7.8	From borrow ditch near well. 6-17-42; 10:00 a.m.; 85°
10-17	White chalky shell marl.		Low permeability. Pumped with pitcher pump for 10 min. at 8 gpm with drawdown of 2′. Would not stand heavier pumping.	54	6-17-42; 1:50 p.m.; 13.4′; 76°. Pitcher pumped.
17-22.5	Brown sand, fine to coarse, in places consolidated poorly to a soft sandstone that crushes between fingers easily. Contains peaty fragments of brown color.	Fort Thompson	Low permeability, very little water available.	74	6-17-42; 2:40 p.m.; 22.5′; 76°
22.5-25.7	Gray-white calcareous sandy shell marl. Broken shell fragments of marine fossils.	25.7	Low permeability, very little water available.	47*	6-17-42; 3:15 p.m.; - 25.7′; 76°
25.7-39.9	Calcareous marl, shelly and sandy. Gray-white color.		Very low permeability. Practically no water available.	58*	6-17-42; 4:30 p.m.; – 36′; 76°
39.9-50	Soft, gray, sandy, calcareous marl, semi-plastic. Comes out of hole quite dry.	Caloosahatchee	Practically impermeable. No water available for sample.	59*	6-17-42; 5:10 p.m.; —39.9′; 76°

* Samples are probably contaminated by surface water which had to be added in order to be able to drill.

Test Well No. GS-6

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-1.5	Road fill.	1.5			
1.5-7.7	Muck and peat.	Recent 7.7	Low permeability.		
7.7-11	White calcareous shell marl with brackish water fossils.	Fort Thompson	At —11′ pumped 10 min. at 15 gpm with pitcher pump. No drawdown. Casing was not solidly seated though and water was being drawn down alongside the casing as well as from marl.	95	6-19-42; 1:15 p.m.; —11′ L.S.; 73°. H_2S odor.
11-14.3	Consolidated sandy shell marl, limestone, and sandstone, with some loose sand. From —12.9 to —14.3 rock is very hard.		At —14.3′ casing was still loose and water is not a true sample at this depth. At —14.3′ pumped 30 min. at 8 gpm with a drawdown of 8 ft.	87	6-19-42; 2:00 p.m.; —14.3′; 74°
				91	6-19-42; 2:45 p.m.; 14.3′; 74°
14.3-18.5	Tan-gray shelly sand or sandy shell marl. Heaves.	18.5	Low permeability.	70	6-22-42; 2:15 p.m.; 18.5′; 74° H_2S odor.
18.5-26.3	Very fine tan-gray sand with a few fossils.		Low permeability.	65	6-22-42; 3:35 p.m.; 26.3′; 74°
26.3-38.5	Tan-gray sandy shell marl, with shells making about 75% of sample. Occasional thin sandstone layers noted. Becomes sandier toward base.		Low permeability.	52	6-22-42; 4:00 p.m.; —30′; 75°
				69	6-23-42; 9:15 a.m.; —38.5′; 74°. H_2S odor.
38.5-43.6	Shell marl, more or less consolidated to sandstone.		Low permeability.	74	6-23-42; 10:40 a.m.; -43.6′; 75°
43.6-55	Shell marl, soft and sandy. Shells comprise 80% to 90% of total sample.	Caloosahatchee	Low permeability, throughout this section.	95	6-23-42; 11:20 a.m.; —47.9′; 75°
			Due to pumping water off the lands farther up the canal, the water level in the canal stood 0.96′ higher than the land surface at the well, and created enough head to produce a flow in the test well from —53.5′ that had a pressure head of 0.13′ above the land surface. Flow was 6.3 gpm.	102	6-23-42; 12 noon; —50.9′; 76°
				121	6-23-42; 3:15 p.m.; —55′; 76°
				117	6-24-42; 9:15 a.m.; —53.5′*° 74°

* Well had caved in to —53.5′ overnight

Test Well No. GS-7

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-2	Road fill.	2		7	From open water of Glades near well. 6-24-42; 4:15 p.m.; 87°
				22	Cross Canal across highway from well. 6-24-42; 4:20 p.m.; 88°
2-13	Muck.	Recent 13	Very low permeability.	10	6-24-42; 4:30 p.m.; —5.5′; 80°
13-16.2	Fresh and brackish water limestone of Fort Thompson age. Fossiliferous. May include the Lake Flirt marl.	Fort Thompson	Low permeability.	24	6-24-42; 5:20 p.m.; —16.3′; 75°
16.2-21.7	Sandy shell marl, in places consolidated to a shelly sandstone.	21.7	Low permeability.	16	6-24-42; 6:15 p.m.; —21.7′; 75°
21.7-29.8	Very fine to fine gray quartz sand with a few shells.	Caloosahatchee	Almost no water recoverable. Low permeability.	56	6-25-42; 10:45 a.m.; —26.4′; 75°
				90	6-25-42; 11:30 a.m.; —29.8′; 75°
29.8-50	Sandy shell marl, light to dark gray, heaves badly so that an open hole cannot be maintained.		Very little water available. Permeability low.	132	6-25-42; 12:30 p.m.; —38′; 75°. Strong H_2S odor.
				1,375	6-25-42; 3:40 p.m.; —50′; 76°. H_2S odor.

Test Well No. GS-8

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-3	White quartz sand, fine to medium.	Pamlico 3	Low permeability.	13	From West Palm Beach Canal across highway from well. 6-30-42; 11:05 a.m.
3-5.3	Calcareous sandstone riddled with solution holes.		Low permeability. Not enough water for a pitcher pump.	7	6-29-42; 12:25 p.m.; —5.3′; 78°
5.3-10	Tan-gray sand and shells.		No water recoverable. Low permeability.		
10-35.3	Tan to brown quartz sand, very fine to medium, most of sand is very fine.	Anastasia	Low permeability. Left casing empty at night. Next morning about 3 gal. of water had seeped in.	258*	6-30-42; 9:30 a.m.; —35.3′; 76°
35.3-44.1	Gray sand with greenish tint. Very fine to fine.		Practically no recoverable water.	288	6-30-42; 11:00 a.m.; —44.1′; 76°
44.1-47	Muddy sand, very fine to medium.	47	No water recoverable.		
47-51	Light gray very fine to medium quartz sand and shell fragments with a hard sandstone layer between —48′ and —49′.	Caloosahatchee	Small quantity of water available, probably coming from the thin rock layer.	218	6-30-42; 1:00 p.m.; —51′; 76°

* Contaminated by surface water used for drilling?

Test Well No. GS-9

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-3	Quartz sand, very fine to medium. Occurs in deep solution holes in oolite.	Pamlico 3	Permeable.	21	From Hillsboro Canal at bridge about 75 yards north of well. 7-1-42; 4:40 p.m.; 78°
3-8	Oolitic limestone riddled by solution holes and filled with Pamlico sand.	Miami 8		29	7-1-42; 4:00 p.m.; —8′; 78°
8-24.1	Quartz sand, muddy, very fine to fine.		No water sample obtainable. Permeability low.	53	7-1-42; 4:30 p.m.; —14′; 78°
24.1-32.5	Sand, as above, and thin layers of brownish black sandy clay marl that is heavy and plastic. Noted much carbonaceous material including roots, root-hairs, bark fragments, etc., evidently an ancient mangrove swamp. Fossils are brackish water type.	Anastasia	Low permeability. Let casing stand empty at night and in morning had enough water to collect a sample.	33 35	7-2-42; 8:20 a.m.; —32.5′; 76° 7-2-42; 9:00 a.m.; —37.2′; 76°
32.5-44.8	Sand, as above, but much more of the black carbonaceous material. Noted pieces of roots, bark, leaves, etc., more of the old swamp deposit.		Water is scarce, but that present is inky black.	32	7-2-42; 9:30 a.m.; —44.8′; 76°
44.8-52	Sand, white, very fine to coarse. Feels and looks like sugar.		Water is a bit muddy but that is due to the over lying material. It is very scarce. Had to wait 3 hours for enough water to seep into casing to get a water sample.	30	7-2-42; 3:00 p.m.; —52′; 76°

Test Well No. GS-10

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-2	Fill.	2		10	From Pompano Canal beside well· 7-6-42; 1:30 p.m.; 85°
2-7.3	Black muck and sticky gray fresh water marl.	Recent 7.3	Very low permeability. Bailed hole dry; took 50 min. to seep full.	15	7-6-42; 1:40 p.m.; —7.3′; 82°
7.3-9	Hard, impure, dark gray sandy limestone, probably of fresh water origin.	Fort Thompson. May also include some Anastasia	Permeability unknown but probably not very high.		
9-10.5	Hard, white calcareous sandstone of marine origin.		A —11.5′ pumped 20 min. at 2.8 gpm with a drawdown of 8.5 feet. Low permeability.	17	7-6-42; 3:05 p.m.; —11.5′; 75°. After pumping test.
10.5-12	White quartz sand and many sandstone nodules.				
12-16.5	Tan-gray calcareous sandstone and chalky limestone. Is soft between —13′ and —16.5′.	16.5			
16.5-21	Hard, tan-gray calcareous sandstone with pockets of sand.	Tamiami	Water flows freely out of casing as well is bailed. High permeability to —21′. At —21.4′ pumped 30 min. at 428 gpm with drawdown of 2.25′.	20	7-7-42; 10:15 a.m.; —22.4′; 77°
		21.0		22	7-7-42; 11:25 a.m.; —21.4′; 75°. After pumping test.
21-22.4	White quartz sand. Heaved in whenever cleaned out.	Caloosahatchee	Low permeability.		
22.4-50	Very fine to fine shelly quartz sand.		Very little water available for sampling. Had to add water in the casing for drilling purposes.	20*	7-7-42; 12:10 p.m.; —23.5′; 77°
				28*	7-7-42; 3:00 p.m.; —34.7′; 76°
				21*	7-7-42; 6:00 p.m.; —50′; 76°

* Possibly contaminated by surface water added for drilling purposes.

TEST WELL No. GS-11

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-2.65	Fill.	2.65		121	Hillsboro Canal near well. 8-4-42; 10:20 a.m.
				35	Glades surface water near well. 8-4-42; 10:30 a.m.
2.65-7	Peat and muck.	Recent	Low permeability.		
7-8.5	Sand and marl.	8.5			
8.5-18.6	Sandy shell marl of dark gray color, and soft enough to crush between fingers.		Whole section is of low permeability. At -14′ pumped 20 min. at 13 gpm with a drawdown of 8.27′.	41	8-4-42; 10:15 a.m.; - 14′; 76°. After pumping test.
				60	8-4-42; 11:35 a.m.; —18.6′; 76°
18.6-23.8	Fine gray-white quartz sand.	Fort Thompson	Low permeability. Could not get enough water for a sample.		
23.8-29.1	Hard calcareous sandstone containing both marine and fresh water fossils. Probably alternating marine and fresh water beds. Section became sandy and shelly at —28.5′.	29.1	Permeable, but of rather low order.	3,150	8-4-42; 2:45 p.m.; —29.1′; 74°. Strong H_2S odor.
29.1-47.4	Very fine quartz sand, shelly in places.	Caloosahatchee	Very little water available for sampling. Low permeability.	3,100	8-4-42; 4:00 p.m.; —29.6′; 75°. Strong H_2S odor.
				3,420	8-4-42; 5:25 p.m.; —38.3′; 75°. H_2S odor.
				3,380	8-5-42; 10:40 a.m.; —40.6′; 76°
				3,400	8-5-42; 12 noon; —47.4′; 75°

Test Well No. GS-11 (Continued)

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
47.4-50.2	Light gray very fine to fine quartz sand and shells with pieces of calcareous sandstone. May be a honeycombed rock filled with sand and shells.		Permeable. Pumped at —50.2′ but could never clear up the sand, and best results we could get were 75 gpm with a drawdown of 2.45′.	3,420	8-5-42; 1:45 p.m.; —50.2′; 75°. H_2S odor. Bailer sample.
				3,400	8-5-42; 3:00 p.m.; —50.2′; 75°. Pumped 20 min. at 14 gpm with drawdown of 1.59′.
				3,400	8-5-42; 4:30 p.m.; —50.2′; 75°. Pumped 20 min. at 75 gpm.
50.2-92.1	Gray quartz sand, very fine to fine, contains a few shells.		Practically no recoverable water. Low permeability.	3,400	8-6-42; 11:30 a.m.; —57.5′; 75°
				3,450	8-6-42; 1:10 p.m.; —61.2′; 75°
		Caloosa-hatchee		3,450	8-6-42; 2:35 p.m.; —68.7′; 75°
				3,450	8-6-42; 3:35 p.m.; —76.2′; 75°
				3,500	8-6-42; 4:30 p.m.; —78.8′; 75°
				3,450	8-7-42; 9:55 a.m.; —82.7′; 76°
				3,450	8-7-42; 1:35 p.m.; —92.1′; 76°
				3,250	8-7-42; 2:10 p.m.; —93′; 76°
92.1-96.7	Soft calcareous shelly sandstone and sand, very similar to interval —47.4′ to —50.2′.		Permeable. Water flows out of casing while bailing out. pumped at —96.7′ for 15 min. at 14 gpm with a drawdown of 0.63′.	3,280	8-7-42; 3:00 p.m.; —96.7′; 76°
				3,380	8-7-42; 4:15 p.m.; —96.7′; 76°. After pumping.

Test Well No. GS-12

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-4	Woody peat (Gandy).		Low permeability, but of a higher order than the peats below.	9.2	From open Glades water near well. 8-13-42; 9:30 a.m.; 82°
4-5	Transition from woody to succulent-plant type peat.				
5-13	Succulent-plant type peat. (Loxahatchee).	Recent	Low permeability.		
13-13.5	Calcareous plastic peat.		Very low permeability.		
13.5-14.4	Sandy marl, white to gray, sticky, fresh water type. (Lake Flirt).	14.4	Practically impermeable.		
14.4-16.5	Dark gray calcareous sandstone with a few marine shells.		Permeable, but not very high.		
16.5-29.8	Gray, sandy shell marl or shelly sand. Sand is very fine to fine white quartz sand, both fresh water and marine shells.	Fort Thompson	Low permeability.	54	8-13-42; 12:15 p.m.; 21′; 75°
				63	8-13-42; 2:15 p.m.; – 29.8′; 75°
29.8-35.8	Greenish-gray shelly sand with pieces of broken sandstone nodules. Sand is very fine to fine quartz grains.	35.8	Low permeability.	63	8-13-42; 3:40 p.m.; —35.8′; 76°
35.8-40	Gray sand and shells and calcareous sandstone or sandy limestone of a dark gray color.		Sandstone yields water readily, and pumping test, though conducted with bottom of hole in sand drew water from rock above. Pumped 20 min. at 155 gpm with drawdown of 2.63′.	36	8-13-42; 5:20 p.m.; 38′; 76°
				40	8-14-42; 9:10 a.m.; 38.5′; 76°
		Caloosahatchee		33	8-14-42; 10:40 a.m.; —41.6′; 77°
40-46.8	Very fine quartz sand of medium-gray color. Thin sandstone layer at —41′.			33	8-14-42; 12:45 p.m.; —41.6′; 77°. After pumping.
				35	8-14-42; 2:00 p.m.; – 46.8′; 77°
46.8-50.2	Shell marl consolidated to shelly sandstone in places; contains many sandstone nodules.		Permeable. Pumped at —50.2′ for 20 min. at 165 gpm, with a drawdown of 2.97′.	35	8-14-42; 3:35 p.m.; —50.2′; 77°
				35	8-14-42; 5:15 p.m.; —50.2′; 77°. After pumping.

Test Well No. GS-13

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-3.5	Fill.	3.5		13	From open Glades near well. 8-25-42; 11:15 a.m.; 82°
3.5-4	Black sticky muck.	Recent			
4-5	Gray white marl.	5		15	Miami Canal near well. 8-25-42; 11:25 a.m.
5-7	Ooltic limestone.	Miami 7		18	8-25-42; 11:50 a.m.; —7′; 78°
7-22.2	Tan-gray calcareous sandstone honeycombed and often filled with sand.	Tamiami?	Pumped at —10.3′ for 20 min. at 133 gpm with a drawdown of 4.07′.	27	8-25-42; 2:50 p.m.; —10.3′; 76°. After pumping.
			Pumped at —14.5′ for 20 min. at 158 gpm with a drawdown of 2.37′.	27	8-26-42; 11:30 a.m.; —14.5′; 76°. After pumping.
22.2-25.5	Hard gray limestone.	22.2		27	8-27-42; 1:50 p.m.; —19.8′; 76°
25.5-33.5	Quartz sand and pieces of calcareous sandstone. May be a solution riddled limestone filled with sand.		Permeable though not of high order.	27	8-27-42; 2:20 p.m.; —26.6′; 76°
				27	8-27-42; 3:10 p.m.; —28′; 76°
				28	8-27-42; 5:00 p.m.; —30.2′; 76°
		Tamiami		29	8-28-42; 10:45 a.m.; —31.2′; 76°
33.5-50	Grayish sandy limestone shelly in places, and containing more or less sand.		Permeability fairly high from —33.5′ to about —48.3′.	29	8-28-42; 1:35 p.m.; —33.5′; 76°
				29	8-31-42; 3:55 p.m.; —40.4′; 75°
				29	9-1-42; 9:40 a.m.; —41.2′; 74°. After pumping.
				27	9-4-42; 3:45 p.m.; —48.8′; 74°. After pumping.
				26	9-4-42; 5:30 p.m.; —50′; 75°. Pitcher pumped.

Test Well No. GS-14

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-1	Black sticky muck.			20	From open Glades water. 9-24-42; 3:15 p.m.
1-2.5	Gray muddy calcareous sandstone or sandy limestone of fresh water origin.	Recent			
		2.5			
2.5-7.5	Tan to gray calcareous sandstone and soft gray marl which probably fills solution holes in the sandstone.		Low permeability. Could get no water sample.		
7.5-10.4	Dark gray to tan quartz sand, very fine to medium. Heaves.	Tamiami	Carries water but casing could never be sealed off so that water entered casing from top to bottom of this section. Permeability fairly low.		
10.4-29.8	Medium to coarse white quartz "sugar" sand, partly cemented with $CaCO_3$ to a friable sandstone. Some parts contain very fine to fine quartz sand. Shelly toward base.		Permeable, but not of high order. A screen well could be made here.	51	9-25-42; 10:30 a.m.; —18.5′; 77°
				68	9-25-42; 12:30 p.m.; —22.5′; 77°
		29.8		92	9-25-42; 2:05 p.m.; —29.8′; 77°
29.8-32	Gray sandy shell marl.		Practically no water.		
32-39.6	Greenish clayey shell marl with a little sand.		Practically impermeable, except in thin sandy streaks where enough water for a sample was obtained.	101	9-25-42; 3:20 p.m.; —35.2′; 77°
39.6-51	Gray shell marl that is consolidated in places to a shelly sandstone. Sand occurs in parts of this section.	Caloosahatchee	Fairly permeable rocks below 50′ but above that the permeability is low. Pumped at —51′ for 20 min. at 153 gpm with a drawdown of 7.25′.	120	9-25-42; 4:40 p.m.; —40.4′; 77°
				114	9-25-42; 6:00 p.m.; —44′; 77°
				228	9-26-42; 11:45 a.m.; —44′; pitcher pump sample.
				220	9-26-42; 3:30 p.m.; —51′; pitcher pump sample.
				228	9-26-42; 4:00 p.m.; —51′; after pumping test.

TEST WELL NO. GS-15 AND 15A

Depth in Feet	Rock Description	Formation Boundaries in Feet	Hydrologic Notes	Chloride in ppm.	Water Sample Notes
0-0.5	Black oxidized peat.		Low permeability.	40	From water in a shallow pit dug into the peat near well. 1-12-43; 11 a.m.; 76°
0.5-2	Brown fibrous peat. (Everglades).		Low permeability.		
2-3	Brown fine grained, succulent-plant type peat (Loxahatchee).	Recent	Low permeability.		
3-3.6	Gray-white fresh-water marl, fills solution holes to depth of several feet in underlying rock. (Lake Flirt).	3.6	Practically impermeable.		
3.6-11	Fresh water and marine limestone and marls.		Rock is quite dense but solution holes give it greater permeability in some portions.	33	1-12-43; 11:30 a.m.; —7.9′; 76°. Pitcher pumped.
		Fort Thompson	Pumped at —7.9′ for 30 min. at 70 gpm with a drawdown of 6.64′.	35	1-12-43; 12:40 p.m.; —7.9′; 74°. After pumping test.
11-13.2	Gray-tan quartz sand with a few fresh water shells.	13. 2	Fairly low permeability.	44	1-12-43; 4:00 p.m.; —12.5′; 74°
13.2-19.5	Hard white sandy limestone containing considerable amount of marine shell. So difficult to drill through that the attempt to complete well had to be abandoned after putting in two wells to same depth.		Pumped at —18.3′ for 5 min. at 18 gpm with drawdown of 0.8′.	111	1-13-43; 10:10 a.m.; —18.3′; 73°. After pitcher pumping test.
		Tamiami?	Pumped at —19.5′ for 40 min. at 100 gpm with a drawdown of 8.38′.	141	1-19-43; 4:00 p.m.; —20′; 74°
				139	1-19-43; 7:15 p.m.; —19.5′; 74°. Slight H_2S odor.
			Continued pumping for 70 min. at 100 gpm, had a final drawdown of 7.67′.	133	1-19-43; 7:45 p.m.; —19.5′; 74°

PROGRESS REPORT ON THE SOIL SURVEY OF THE EVERGLADES

M. H. Gallatin [1] and J. R. Henderson [2]

The soil survey of the Everglades Drainage District was initiated by the Soil Conservation Service in January, 1940.

At the meeting of the Soil Science Society of Florida in West Palm Beach last year, Evans and Allison [3] gave a report on the progress of the survey, in which they emphasized the importance of water control for soil conservation in both cultivated and uncultivated areas, and outlined in a general way the characteristics of the more important soils. The present report will cover the status of the survey as of March, 1943.

DESCRIPTION OF AREA

The Everglades Drainage District comprises approximately 7,000 square miles. The Everglades proper, which makes up the interior of the District, slopes gently southward from elevation 18 feet (Okeechobee datum) at Lake Okeechobee to sea level in the southern extremities of the peninsula. The "Glades" are flanked on either side by sandy ridges.

General Soil Groups

The District has within its boundaries four distinct groups of soils: (1) organic, (2) sands, (3) rockland, and (4) marls.

The main body of the Everglades, which begins at Lake Okeechobee and extends southward, is an extensive treeless plain, the soils of which are derived mainly from sawgrass. However, in the eastern part, above the Hillsboro Canal, and along the western side of the Everglades, are areas of organic soils derived from more aquatic types of growth such as lilies, water grass, bonnets, and cat-tails. These areas are wet, shallow

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[1] Assistant Soil Technologist, Soil Conservation Service, Ft. Lauderdale, Fla. Prior to his graduation from the University of Wisconsin in 1938, after having started his work there in 1924, Mr. Gallatin was associated with the Marshfield and Ashland Branch Experiment Stations of the University of Wisconsin and with the soil survey of that state from 1926 to 1930, and subsequently served first as Junior and later as Assistant Soil Chemist with the United Fruit Company, Tela, Honduras, 1933-36. Following graduation he was Assistant Soil Surveyor with the University of Tennessee from 1939 to 1940 and after a year's service with the Division Engineer's office of the Chicago, Milwaukee, St. Paul and Pacific R.R. Company, accepted the present assignment with the Soil Conservation Service where he is now Party Chief in Charge of the Everglades Soil Survey.

[2] Soil Technologist, Florida Agricultural Experiment Station, Gainesville. Following graduation from University of Florida in 1934 with an M.Sc. degree in agriculture, Mr. Henderson accepted a position as Soil Surveyor with F.E.R.A. (1934-35) and subsequently held the same position with the Bureau of Agricultural Economics and Rural Resettlement Administration, successively, through 1935-37. During this latter period he made a reconnaissance soil survey of the entire State. In 1937 he became Assistant Soil Chemist at the Florida Experiment Station, Associate Chemist in 1939 and in 1942 was made Soil Technologist in charge of the State Soil Survey.

[3] Evans, Charles B. and R. V. Allison. The soils of the Everglades in relation to reclamation and conservation operations, Soil Science Society of Florida, Fourth Proceedings, Volume IV-A, pp. 34-46. 1942.

sloughs and are interspersed with wooded islands of varying size, usually oblong in shape. The islands are covered with a heavy growth of bay, myrtle, and ferns. The islands in the Hillsboro area are oriented in a south-southeasterly direction, and those to the west of the Miami Canal are oriented in a south-southwesterly direction. The orientation of these islands is the result of the drainage pattern developed in the Everglades in the recent geologic past.

Adjacent to the organic soils and at somewhat higher elevation on the eastern and western sides of the Everglades, areas of sandy soils are mapped. On the eastern side, this sandy ridge varies in width from 8 to 10 miles. There, the sands are, in general, shallow, ranging in depth from a very few inches to 5 or 6 feet. The topography of the area is flat to gently undulating. The natural vegetation is mainly pine and palmetto.

Along the western edge of the Glades the sandy area is generally level, though interspersed with sloughs and ponds. The northern part of this section, starting in the vicinity of the lower boundary of the Indian Reservation, has a cover of pine and palmetto, while to the south the cover is mainly cypress, with pine and palmetto and some native grasses on the higher portions.

In the vicinity of Miami and extending southward and westward through Homestead the Miami oolite comes to the surface as the exposed rock. The inner edge of the rockland, adjacent to the Everglades, lies at a somewhat lower elevation than the rest and is void of any soil material except small, scattered patches of shallow peat which still remain.

The main portion of the rockland lies at a higher elevation and has a natural cover of pine and palmetto. In the vicinity of South Miami, the rock has a shallow covering of sand but in the vicinity of Homestead it contains pockets of clay or of sand and clay intermixed.

The coastal marshes, in which the soils are marls, lies between the old rock rim and the ocean in the southern part of the district. The topography of this area is that of a flat plain lying at an elevation of about 8 feet near Homestead and gradually sloping to sea level at the coast. The marl probably was formed largely by fresh-water organisms. The dominant vegetation is sawgrass with small clumps of bay and myrtle arranged along the drainage courses. Near the coast on the saline phase of the marl soils, the vegetation changes to red and black mangrove.

Relation of Geology to Soils

While the underlying rock formations within the Everglades Drainage District apparently do not have a direct relation to the physical or structural characteristics of the soil, they do markedly affect their drainage characteristics and have a definite influence on soil reaction.

In the northern portion of the District, from Lake Okeechobee east to the coastal ridge and south to about 20-Mile Bend in the North New River Canal, the area is underlain by Fort Thompson limestone, as indicated on Parker's geological map to be found on page 35 of this volume. This formation is relatively impervious to water movement. The major portion of the deeper organic soils is underlain by this formation. Directly upon the Fort Thompson there is found over most of the area a layer of Lake Flirt marl. While this layer is not consistently found

between the organic mantle and the underlying limestone, where it does occur it seems to act as a seal to keep down sub-surface waters.

On Parker's geological map referred to, Fig. 1 p. 35, there is shown a large area of Miami oolite south of the Fort Thompson. This is a highly soluble formation which, from water action during the past geologic time, has become very jagged and pinnacled and full of solution holes, so that water flows through it freely. This formation underlies most of the organic soils in Dade and Broward Counties, and also the soils of the coastal ridge south of the Hillsboro Canal to the southern end of Florida. To the west of the oolite formation in the vicinity of 40-Mile Bend on the Tamiami Trail, is found the Tamiami formation. This is more or less like the oolite in its water-bearing characteristics. Most of the area in which this formation occurs is overlain by a shallow marl.

To the north of the Hillsboro Canal along the coastal ridge is found the Anastasia formation. This was probably deposited contemporaneously with the Miami oolite and as a sandy facies of it. It underlies the coastal ridge from the Hillsboro Canal northward. Though like the oolite in many respects, the permeability of the Anastasia is generally lower. All of these geological relationships are discussed in considerable detail by Parker and their implications in the matter of water control from an agricultural standpoint are reviewed by Stephens in this same volume, pp. 33-94.

PROGRESS OF THE SURVEY

When completed, the survey will cover the entire Everglades Drainage District and the coastal area from West Palm Beach southward to Cape Sable. Of this area, totaling about 7,250 square miles, approximately 5,800 square miles had been surveyed up to March, 1943. The portion yet to be covered consists mainly of the northern end of the District, east and west of Lake Okeechobee. A number of soil types and phases have been recognized in each of the broad classes previously referred to, each of which is to be described in some detail in the pages that follow.

AGRICULTURALLY IMPORTANT ORGANIC SOILS

The agriculturally important types of organic soils mapped in the Everglades are: Okeechobee muck, very deep and deep phases; Okeelanta peaty muck, very deep and deep phases; Everglades peat, very deep and deep phases; and Everglades peat over sand, very deep, deep, shallow, and very shallow phases. Separation of each type into phases on the basis of depth of organic material has been made as follows:

More than 96 inches, very deep phase.
60 to 96 inches, deep phase.
36 to 60 inches, shallow phase.
Less than 36 inches, very shallow phase.

The location and boundaries determined for each type and phase of soil mapped in the survey to date (March, 1943) are shown in Figure 1.

Okeechobee Muck

Okeechobee muck, locally known as "Custard apple land", is the most valuable of the organic soils in the Everglades. It occurs in the

vicinity of Lake Okeechobee along the south and southeastern shores of the lake in a zone varying in width from 1 to 3 miles. It is a heavy, black, plastic muck containing a comparatively high percentage of fine sand, silt, and clay (35 to 70 percent by loss on ignition.) When wet it is plastic and sticky, but upon drying it becomes hard and compact, and cracks. In cultivated fields it usually breaks down into a deep, dusty mulch when the water table becomes too low. This heavy material is very uniform and is generally underlain at 30 to 60 inches by a brown, fibrous peat which rests directly on the limestone. The very deep phase of this muck borders the eastern rim of the lake; the deep phase occurs along the south shore. All of this type is underlain by the Fort Thompson formation.

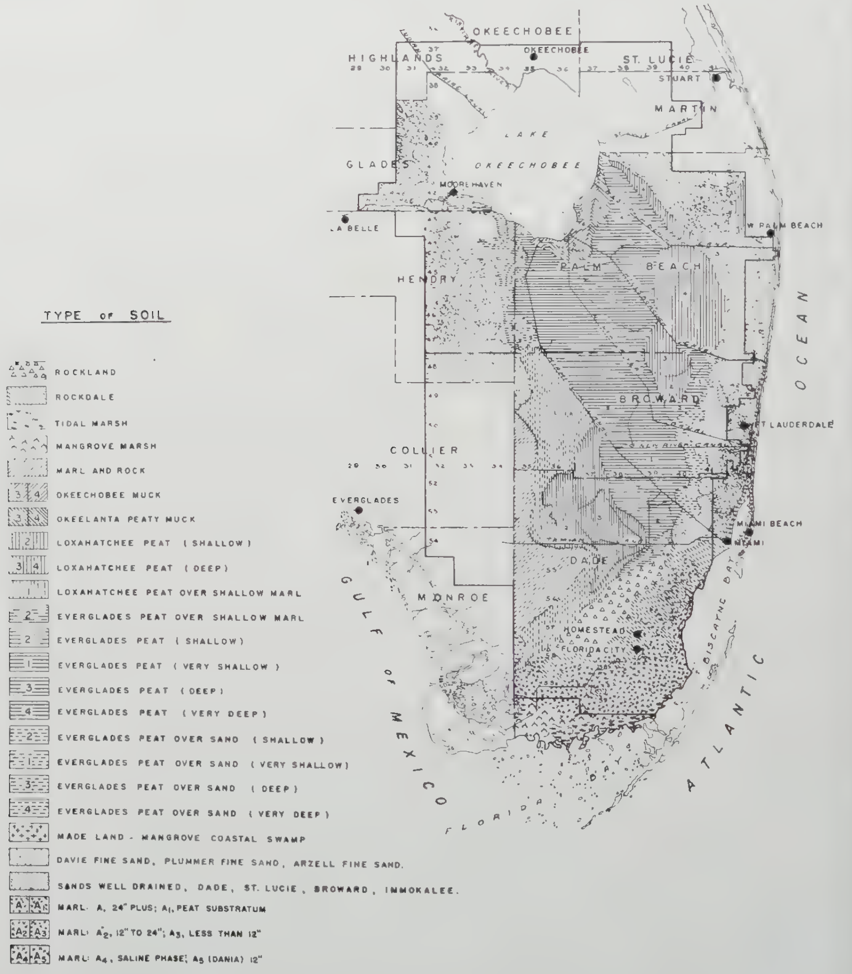


Figure 1.--Soils map of the Everglades Drainage District showing distribution of types found and progress of work to date of March, 1943.

Okeechobee muck is very desirable for the production of sugar cane and truck crops. Because of less subsidence in this type, and for other reasons, it is relatively higher than most of the other soils of the area. Drainage is usually better on it but during certain periods of the year it becomes very dry and irrigation is necessary, especially for truck crops. Approximately 25,000 acres of this type have been mapped to date.

Okeelanta Peaty Muck

This type, locally called "willow and elder land," borders the Okeechobee muck and is transitional between Okeechobee muck and Everglades peat. As usually mapped this soil has three distinct layers: (1) the surface 6 to 12 inches of finely fibrous, decomposed peat, (2) a layer of plastic, sedimentary muck which varies in thickness from 2 to 30 or more inches, and (3) another layer of fibrous, brown peat. Variations in the arrangement of strata frequently occur and layers of peat and muck are alternated. Due to drainage, oxidation, burning, and subsidence, the peaty surface material in places has become mixed with the layer or layers of muck resulting in a peaty muck surface which is higher in mineral content than normal. To date, approximately 30,000 acres of this type have been covered by the survey. As will be noted by comparing the soil map of Figure 1 with Parker's geological map on page 35, this type also is underlain by the Fort Thompson formation. While not as productive as Okeechobee muck, this soil is well suited to the growth of sugar cane and truck crops, field crops and pasture grasses.

Everglades Peat, Very Deep and Deep Phases

Everglades peat, locally known as sawgrass land, is the most extensive soil type in the Everglades. It consists of 6 to 18 inches of black, finely fibrous, partially decomposed organic matter which grades gradually into a brown, fibrous peat. Between the organic material and the underlying rock is usually found a mixture of decomposed organic material and marl. A layer of this marl (Lake Flirt) has been found throughout the area except where the peat is underlain by sand. All of the very deep and deep phases of Everglades peat is underlain by the Fort Thompson limestone.

To date, approximately 125,000 acres of the very deep phase and 225,000 acres of the deep phase have been mapped. While not naturally as fertile as the Okeechobee muck or Okeelanta peaty muck, when water control is provided and necessary fertilizer amendments are supplied these soils will produce excellent crops of sugar cane, truck, and pasture grasses. At the present time only a relatively small portion of the Everglades peat is used for agricultural purposes. Those areas of very deep and deep phases of Everglades peat which at present are not in cultivation should be protected from loss, through burning and subsidence, by raising the ground water table to the surface or above.

Everglades Peat, Over Sand

Two areas of Everglades peat over sand have been mapped. The deeper area lies in the western and northern part of the Everglades Drainage District southwest of Clewiston, and the shallow phase borders the mineral soil in the eastern part of the District. Everglades peat over sand is similar in profile characteristics to the normal Everglades

peat except that between the organic soil and the underlying marl or limestone a layer of sand of varying thickness occurs. The area of Everglades peat over sand (shallow phase) in the eastern part of the District, though underlain by the permeable oolitic limestone,[4] can be utilized after the surface organic material has been lost because the sand is of sufficient depth that farming can be carried on and water control can be effected without breaking into the porous oolite rock.

At the present time the area on the west is not developed. The area on the east, in the vicinity of Davie, is being utilized for citrus, improved pastures, and truck crops. To date approximately 130,500 acres of this phase have been mapped.

NON-AGRICULTURAL ORGANIC SOILS

The organic soils of the Everglades that are considered to be of little or no potential agricultural value are: Everglades peat, shallow phase; Everglades peat, very shallow phase; Everglades peat over shallow marl; Loxahatchee peat, very deep phase; Loxahatchee peat, deep phase; Loxahatchee peat, shallow phase; Loxahatchee peat, very shallow phase; and Loxahatchee peat, shallow phase over shallow marl. The depth separations are made as already outlined for the agriculturally important organic soils.

Everglades Peat, Shallow and Very Shallow Phases

Insofar as profile characteristics are concerned, there is little difference between the shallow and very shallow phases of Everglades peat and those phases having a depth of 5 feet or more. The shallower depths are classed as non-agricultural, however, because 5 feet seems to be the minimum depth that will provide for the subsidence of ground surface that occurs in the peat soils with drainage and cultivation, and, at the same time, allow for a sufficient period of cultivation so that the crops upon the land will pay for the reclamation. To visualize too long periods of cultivation for such soils would mean excavating the ditches into the rock and this probably would make the cost of drainage greater than the lands could pay. Moreover these phases are underlain by oolite and, as pointed out in preceding papers, adequate water control on this type of rock does not appear feasible.

At the present time little of this land is being used for anything other than dry weather grazing. Probably the best use for these areas would be the storage of extensive water reserves.

Everglades Peat, Over Shallow Marl

One small area of this phase of Everglades peat was mapped west of Miami. It is underlain by a shallow layer of marl between the organic material and the sub-surface rock, but it is not deep enough to warrant reclamation, nor is the rock of such type that water control can be effected. This area at present is used for dry weather grazing.

Loxahatchee Peat, Very Deep and Deep Phases

These are the deepest of the non-agricultural soils. Approximately

[4] See geological map by Parker and Hoy, p. 35, this volume.

250,000 acres of the very deep and deep phases have been mapped to date. The soil consists of a very spongy, felty, brown, fibrous material derived from more succulent plants than is Everglades peat. This area also is underlain by Fort Thompson limestone, and between this and the peat is usually found a layer of Lake Flirt marl varying in thickness from 3 to 12 inches.

Although this peat is 8 to 12 feet deep in the main body lying north of the Hillsboro Canal, under present economic conditions it should not be considered for development. With the initial lowering of the water table, subsidence would be great and at least three years of preliminary drainage and oxidation would be necessary before the land could be used for agricultural purposes. Drainage or lowering of the water table in this area also would undoubtedly affect the air temperature and water control in the areas of mineral soils lying to the east. Under existing agricultural conditions, the best use for these soils would be as a wildlife and water conservation area.

Loxahatchee Peat, Shallow and Very Shallow Phases

To date approximately 160,000 acres of the shallow and very shallow phases of Loxahatchee peat have been mapped. These areas occur in the southern and western parts of the Everglades District. Because of the permeable nature of the underlying rock and the shallowness of the peat, these areas, also, are best adapted for wildlife and water storage.

Loxahatchee Peat, Shallow Phase Over Shallow Marl

This phase of Loxahatchee peat was mapped in the western part of the area in the vicinity of 40-Mile Bend on the Tamiami Trail, and southward. It was derived from the same type of materials as described heretofore. The main difference is that this phase has a shallow layer of marl between the organic material and the underlying rock. Approximately 160,000 acres of this type have been mapped.

Due to position and type of material, this phase under present economic conditions is not considered as agricultural. The best use for the area under present economic conditions would be as a wildlife and water storage area.

MARLS

The various types and phases of marls so far recognized in the Everglades Drainage District are: Perrine marl; Perrine marl, shallow phase; Perrine marl, very shallow phase; Perrine marl, saline phase; Perrine marl, peat-substratum phase; Flamingo marl; and Ochopee marl. The depth phases of Perrine marl are as follows:

Perrine marl, more than 24 inches deep;

Perrine marl, shallow phase, 12 to 24 inches deep;

Perrine marl, very shallow phase, 6 to 12 inches deep.

According to the geological map referred to above, Parker and Hoy, p. 35, this volume, all of these marls are underlain by Miami oolite or Tamiami limestone and for this reason adequate control of water is quite difficult. The northern part of the eastern marl area east of Goulds

where the ocean-level canals have been dug, is fairly well drained. It lies at a somewhat higher elevation than the section south of Homestead and Florida City where, because of the low elevation and the type of underlying rock, agricultural development should be undertaken only after a careful study of local conditions has been made.

Perrine Marl

The normal type, which is more than 24 inches in depth, is found in the southern and southeastern part of the Everglades Drainage District starting in the vicinity of South Miami and extending southward and westward along the coast, with numerous "glades" breaking through the Rockdale rockland toward the interior. According to Parker and Hoy, pp. 33-55 of this volume, Perrine marl was laid down in fresh water whereas the Flamingo marl in the vicinity of Flamingo and Cape Sable was laid down in brackish water. The Perrine marl consists of a light, brownish-gray silt loam of uniform texture and smooth, mellow, friable structure throughout. Chemically, it is calcium carbonate intermixed with organic material. This dries out to a light gray or yellowish gray. and ranges in depth from 8 to 40 inches or more.

The Perrine marl, when drained, grows excellent truck crops, which is its main use. However, because of its physical make-up water moves through it very slowly. For this reason, development of the portions not now in cultivation should proceed along the following lines: The areas selected should have such a depth of soil that drainage can be obtained without breaking into the permeable underlying rock. The area should be diked, and shallow ditches dug so that excess water will run over the surface rather than slowly seep through the soil. If the ditches are kept above the porous rock below, water control can be effected.

The area of the Perrine marl so far mapped, including the four phases named, is approximately 64,000 acres.

Perrine Marl, Shallow and Very Shallow Phases

These phases of the Perrine marl have the same profile characteristics as the normal soil except that they are not so deep to the underlying rock. Adequate water control would not be possible on these phases because the soil depth over the water-bearing rock is insufficient for the proper construction of drainage ditches.

Perrine Marl, Peat Substratum Phase

The peat-substratum phase has one or more layers of organic material 6 to 8 inches below the surface. It occurs in close association with and is similar to Perrine marl in agricultural use and adaptations. However, if the organic layer is intermixed with the surface marl it should give a looser, more friable soil.

Perrine Marl, Saline Phase

The saline phase is similar to the typical soil but lies at a lower elevation and is covered or affected by the tides.

Flamingo Marl

This soil consists of a smooth gray to grayish white friable material in the surface becoming more compact with depth. Usually at about 30 to 35

inches a compact more or less plastic material having a greenish cast is encountered.

Ochopee Marl

This marl occurs on the west side of the Everglades Drainage District in the vicinity of the Tamiami Trail and extends south and southwest therefrom. It consists of a smooth, friable, dark gray to steel gray material varying in depth from practically nothing to 10 or 12 inches. As mapped in this area, it is a condition rather than a definite soil. In places the material has sufficient depth and could be farmed, but these locations occur at such relatively low elevations and are so closely underlain by the Tamiami formation that control of water would be exceedingly difficult. Though this soil is used for truck crops farther west, in the vicinity of Everglades, within the District its low position and the type of underlying rock make it unsuitable for agriculture.

SANDS

While the higher strip of land between the Everglades and the Atlantic Ocean includes many soil series, for the present discussion they have been divided into two groups. The first group consists of the soils lying at an elevation intermediate between the organic soils of the Glades and the higher mineral soils of the coastal ridge, and are classified as poorly drained. They are Davie mucky fine sand and fine sand, Arzell fine sand, Plummer fine sand, and Portsmouth fine sand. Although there are differences in the inherent fertility of the various members of this group of soils, this will not be considered here since all are used for truck crops, with different types of amendments and fertilizers to attain maximum production. The Davie mucky fine sand is being used for citrus, while the Davie fine sand at present is utilized mainly for pasture. The most important difference between this group and the sands lying at a higher elevation is that control of water on the first group is feasible. To date, approximately 170,000 acres of these soils have been mapped.

The soils of the second group, the well drained to intermediately drained sands, are found on the coastal ridge. They are St. Lucie fine sand, Dade fine sand, Broward fine sand, Immokalee fine sand, and Leon fine sand. In the past, some soils included in this group were farmed. Due to excessive drainage and a resultant lowering of the water table in this coastal area, however, proper water control without excessive costs is not attainable.

Of this group, the Broward, Immokalee and Leon are used for pasture. The St. Lucie and Dade, because of the depth of sand, topography, and type of underlying rock, cannot be considered as agricultural. Approximately 350,000 acres of these soils have been mapped to date.

ROCKLAND

Three types of rockland were mapped: Rockdale rockland; Rockdale rockland, clayey phase; and Rockdale rockland, sandy phase. The first is regarded as non-agricultural.

Rockdale Rockland, Clayey Phase and Sandy Phase

Rockdale rockland consists of oolitic limestone, a light gray, soft, porous, and honey-combed formation with numerous holes and cavities, which are filled with reddish clay or gray fine sand. Prior to using this rockland for agriculture, it is necessary to scarify the surface and dig or blast holes in it for planting trees. The clayey phase consists of the porous oolite material with the cavities and holes filled with a brown, fine sandy clay loam or yellowish-red sticky clay. Locally, this phase is considered slightly better for citrus and other fruit than the sandy phase.

The sandy phase of Rockdale differs from the clayey phase only in having gray or grayish yellow sand in the holes or cavities. This phase grades into the Dade fine sand in the north and the clayey phase in the south and west.

Both of these types are used for the production of avocados, citrus, and mangoes, and to a small extent for truck crops.

MISCELLANEOUS LAND TYPES

Two miscellaneous land types were classified: Tidal marsh (mangrove swamp) and made land.

All of the land included in the above types is non-agricultural. The mangrove swamps are affected daily by tides. Their best use is for wildlife and recreational purposes. The made land, most of which was mapped in the vicinity of Miami, is a miscellaneous assortment of materials most of which were dredged or pumped from the ocean and Inland Waterway.

SUMMARY

Of the 7,000 square miles in the Everglades District, 5,800 have been surveyed and mapped during the course of the soil survey initiated in 1940 by the Soil Conservation Service. The information obtained to date indicates that approximately 435,000 acres of the land in the District are suitable for long-time use for crop production. While some of the remainder may well be used for improved and native pasture, the greater portion should be used as a wildlife refuge and for water storage.

The suitability of the soils for agricultural use depends on many factors of which the more important are: the character of the soil material, the depth of the soil, and the permeability of the underlying formations. Certain combinations of these characteristics will permit the development of a permanent agriculture, whereas others will not. A careful study and evaluation of these factors should precede the opening of new areas to settlement. When the survey of the District is finished a complete body of information outlining the potentialities of the Everglades will be available to all interested parties.

Chairman Mossbarger:

Thank you Mr. Gallatin. As this program progresses, we learn more and more the value of these different phases. Certainly we should not think of doing anything in the way of serious planning for the Everglades area until this portrait of the land, the soil survey, is fully completed.

The next subject is fully as important as any other. We will now hear from Dr. John Henry Davis who will speak to us on "The Vegetation of the Everglades and Conservation from the point of view of the Plant Ecologist." Dr. Davis.

VEGETATION OF THE EVERGLADES AND CONSERVATION FROM THE POINT OF VIEW OF THE PLANT ECOLOGIST [1]

John H. Davis, Jr. [2]

The plant ecologist attempts to find out about those natural features of a particular region which most directly influence plant life. In so doing he often is able to aid in determining the best use of the land and in the development of conservation programs. In the Everglades, where the vegetation has been the main source of the organic soils, an understanding of the plant life and the physical conditions that influence it are very important. The effects of the changed water conditions in this region have been amply discussed at this and other meetings, but we need also to consider the natural vegetation and the wildlife in any comprehensive and unified program of conservation. For this purpose there is briefly outlined herewith the main types of vegetation and certain general conclusions regarding conservation.

In the first place the Everglades is not a uniform region of marshes almost completely dominated by saw-grass as many persons have supposed. It is by definition, and by the usual boundaries applied to it, a region without many trees and dominated by grasses, sedges, reeds, rushes, and other herbs growing on peat, marl, or even sandy soils that are nearly level, and which are flooded or wet nearly to their surface most of the year. The pine, cypress, mangrove, and other forests bordering the Everglades are not part of the Everglades although some of these types of vegetation occur in the Everglades basin. There are, moreover, within the broader expanse of the marshes some prairies, sloughs, ponds, and many island-like groups of trees which stand out like oases on a desert, and which will be referred to as tree-islands. There are bay-heads, hammocks of hardwoods and palms, myrtle thickets, groups of willows, and even other groups of tree and shrub vegetation. But these trees and bushes do not cover large areas or make the Everglades a swamp region as some persons have described it.

From the point of view of the plant ecologist these marshes are like "low moors" which are similar in some respects to bogs because peat deposits accumulate in them.

On the vegetation map, Figure 1, p. 106, are shown most of the types in the Everglades. These are, or were until recently, with the general areas they cover, the following:

(1) The custard apple and willow-elderberry zones of swamp trees

[1] An abstract of certain sections of Florida State Geological Survey Bulletin 25, published by Dr. Davis subsequent to the Belle Glade meetings of the Soil Science Society of Florida.

[2] Research Assistant, Florida Geological Survey, since 1941. Formerly professor of Biology, Southwestern University, Memphis, Tennessee, and Research Associate of the Carnegie Institution of Washington. During his connection with the Carnegie Institution his research in Florida included studies of the types of mangrove vegetation and their geologic role, and of the Florida Keys west of Key West.

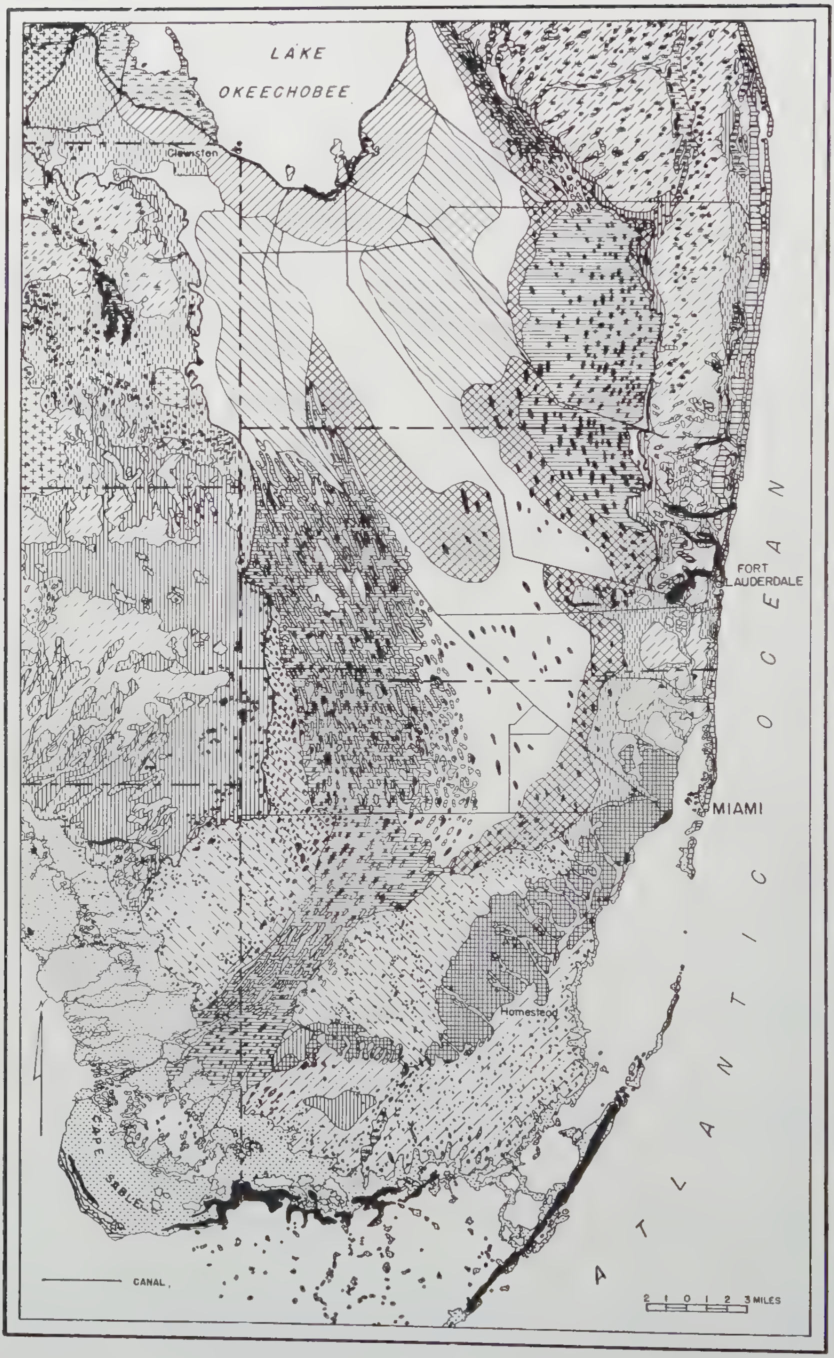
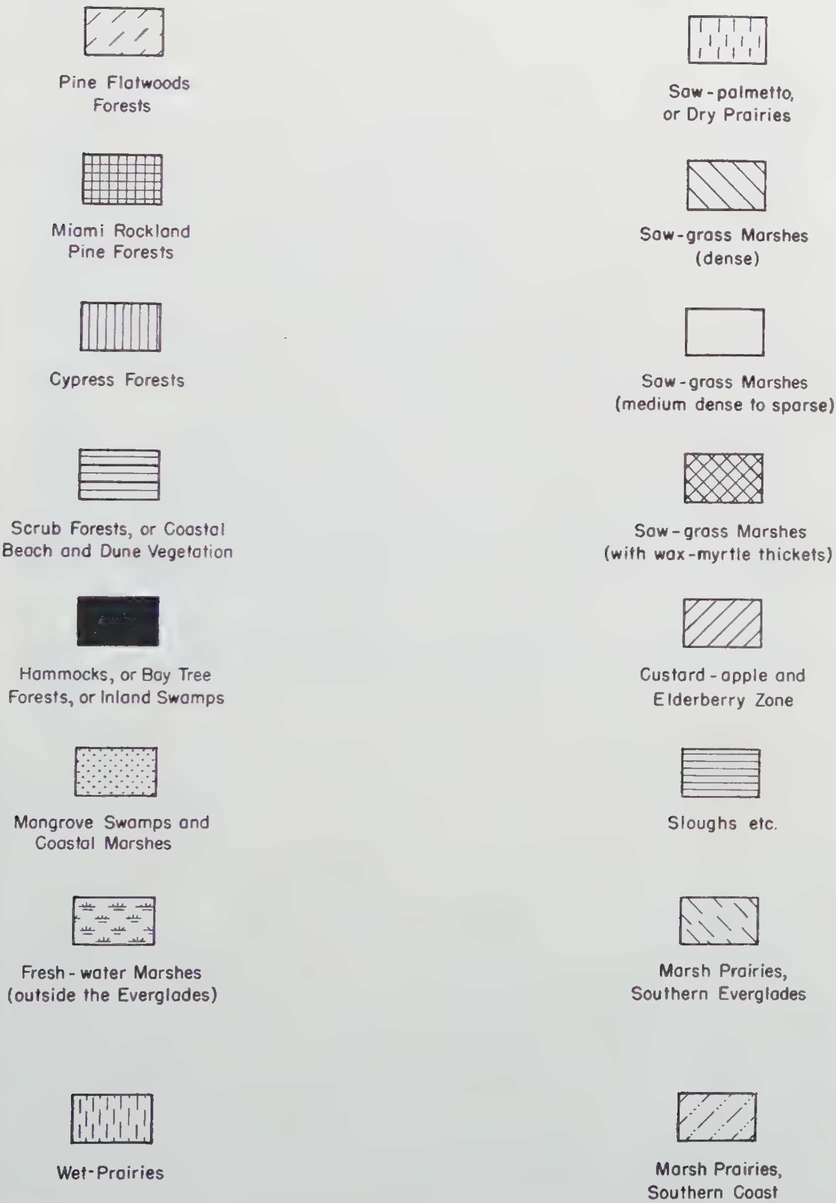


Figure 1.—A vegetation map of the Florida Everglades and adjacent areas.

EXPLANATION

Figure 1



and bushes which formerly extended as a wide swamp belt around the southern shore of Lake Okeechobee from a few miles north of Canal Point on the east to a few miles north of Moore Haven on the west.

Nearly all of this swamp zone has now been cleared and is under cultivation.

Figure 2.—Trail made by tractor through a medium dense growth of saw-grass in the Everglades. At this season, April 1942, the plain was not covered by water except in low areas.

(2) The saw-grass marsh plains, Figure 2, is covered by dense to sparse saw-grass growth, with a few commonly associated sedges, grasses, ferns, and other herbs, but with very few or no bushes and trees.

These dominantly saw-grass plains cover most of the northern and central Everglades southward to slightly below part of the Tamiami Canal and Trail. Most of this almost unbroken marsh was once densely covered with tall saw-grass, but drainage, consequent subsidence of the peat soil, and fires have thinned out the natural plant cover and promoted the growth of weeds, bushes, and other plants, until many areas now have only medium to very sparse growth.

(3) The saw-grass and wax-myrtle (or bay-berry) thicket areas, varying from nearly uniform saw-grass with a few scattered wax-myrtle bushes to nearly pure wax-myrtle thickets, covering a large area between the North New River and Miami Canals and extending as a border between the more uniform saw-grass plains and other types of vegetation along the eastern side of the central saw-grass plain.

This type of vegetation is a part of the saw-grass marshes, being mainly a transitional zone between the nearly uniform saw-grass marshes and the slough and tree-island areas.

(4) The slough and tree-island areas, with mainly open water, aquatic vegetation, and groups of trees. Figures 3 and 4. Besides these features there are elongated strands or breaks of saw-grass, other mixed marshes, and willow and wax-myrtle bushes.

There are two large areas of this mixed type of herbaceous and tree vegetation. One of these is the old Barnett Lake area, now often known as Hillsborough Lake or Big Lake. It is a wide area with numerous ponds or lakes lying between the range line road, State Highway 199, and the Hillsborough Canal. The other area of this mixed vegetation lies to the west of the Miami Canal, beginning near the north Broward County line and extending in a southeast then southwest direction form-

Figure 3.—A flat-bottomed "air boat," driven by an airplane propeller on one of the sloughs of the Hillsborough Lake area. Here the aquatic plants form a Loxahatchee peat. In the background are bushes and trees of the tree-islands where Gandy peat is found.

ing a great arc that ends in the Shark River — Whitewater Bay area (see Figure 1). The sloughs are usually water-filled, except in very dry seasons, and, on the ridges, tree-islands develop that have a characteristic ovoid shape, Figure 4. Its southwest trending southern part is shaped like a funnel and extends southwestward between the two southern mixed marsh and wet-prairie areas. In this section there are long, saw-grass strands as well as tree-islands that are usually separated from each other by sloughs which drain water toward the southwest coast.

Since large parts of these sloughs and tree-island areas have a very loose textured peat, called Loxahatchee peat, they are often referred to as the Loxahatchee peat areas, this peat having been formed in the sloughs by the growth of aquatic plants which usually precede the growth of saw-grass.

Another feature of the western slough and tree-island area is the fact that most of the elongated sloughs, long saw-grass marsh areas known as strands, and tree-islands are all oriented in the same general direction. This orientation of the vegetation seems to correspond to both the drainage and topography. The tree-islands are characteristically oval-shaped with the blunter end directed northward, or against the natural direction of flow of water in the sloughs, thus showing that vegetation and drainage develop in conjunction with each other. In fact, it is entirely possible that small groups of taller herbs, then shrubs, and finally trees developed in a sequence of stages as a consequence of the slowing down of the water currents in the sloughs through the agency of vegetational growth, possibly by tussock formation.

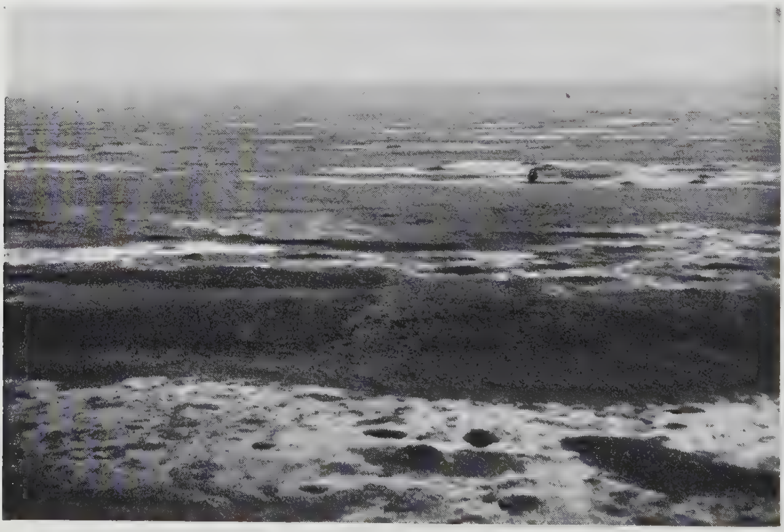


Figure 4.—Aerial view of part of the western slough and tree-island area, T. 50 S. R. 36 E., showing elongated sloughs (light areas) with aquatic plants, and elongated or oval shaped islands of trees and bushes (darkest areas), with saw-grass marshes between the sloughs and the tree-islands.

(5) The southern mixed marshes and wet-prairies on marl soil or rockland represented by two areas mostly south of the Tamiami Trail that lie to the east and west sides of the southern part of the Everglades.

The vegetation is a growth of low and sparse marsh plants commonly with patches of saw-grass, or of switch-grass and other grasses and some marsh plants that form wet-prairies, so that it is difficult to designate them as either marshes or prairies. Over these low-lying marshes and prairies many sub-tropical hammocks are scattered on the higher and usually rockier parts while some groups of bay trees and wax-myrtle occur at lower elevations. Some areas have very little marl, or are so thinly covered that the surface is very rocky and rough with solution holes and other erosional features. These rockland, prairie-like areas are common on the southeast side adjoining the Miami Rock Ridge pinelands. Parts of these plains are prairie-like with scattered cabbage-palms and hammocks of tropical hardwood trees.

(6) Bordering prairies of low to tall grass vegetation of seasonally wet soils growing mainly on sand areas that form narrow zones.

These prairie zones with scattered hammocks, cypress, bay trees and pines, flank parts of both the eastern and western sides of the Everglades. The eastern prairie zone extends along the pineland border of the Glades from a few miles north of the North New River Canal to South Miami. The prairie zone of the western border extends from Fisheating Creek into the upper part of the Caloosahatchee River Valley, then south along the border of the Hendry County pine flatwods until it touches on part of the Big Cypress region. In fact, the western border prairies extend far out of the Everglades proper and even out of the Everglades basin because they continue all the way up the Caloosahatchee valley to LaBelle, and west into the southern part of Hendry County to the Ocaloacoochee slough. Only those sections near the Everglades marshes or near Lake Okeechobee are considered part of the Everglades, the other areas being parts of the flatwoods region, characteristic of this section of the State. Both the eastern and western border prairie areas are thus transition zones of vegetation between the saw-grass marshes, or other central Everglades vegetation, and the forest vegetation of pine flatwoods or cypress forests. Those prairies along the east border were formerly much more marsh-like with thin peat or muck soils over sand, but since much of this border zone has been drained and some of it cultivated the top peat or muck layer has largely disappeared so that these formerly marsh areas are now essentially grassy prairies on the sandy soils that have been left after the disappearance of the covering layer of organic soils.

The transverse glades that are prairie and marsh extensions of various parts of the Everglades out through the eastern border pinelands likewise are not here considered as parts of the Everglades proper although they are referred to by residents of this section as glades. They are mostly drained and cultivated as their muck and marl soils have proved to be good agricultural lands.

Similarly the large southern coastal prairie and marsh area lying between the Miami rockland pine forests and the southern coast is not considered a part of the Everglades for most of it is not in the Everglades basin and much of it is now under cultivation.

The total areas covered by each of these types and some of their sub-types are approximately as follows:

1. Custard-apple and willow-elderberry zones		140,000 acres
2. Saw-grass marsh plains		1,000,000 acres
Dense saw-grass	350,000 acres	
Medium dense to sparse saw-grass	650,000 acres	
3. Saw-grass and myrtle thicket marshes		240,000 acres
4. Slough and tree-island areas		775,000 acres
Eastern or Hillsborough Lake area	200,000 acres	
Western and southwestern area	575,000 acres	
5. Southern marshes and wet-prairies		300,000 acres
Eastern area	125,000 acres	
Western area	175,000 acres	
6. Bordering prairies		145,000 acres
Eastern border	60,000 acres	
Western border	85,000 acres	
EVERGLADES TOTAL		2,600,000 acres

The custard-apple swamps no longer exist as such and nearly all the willow and elderberry zone also has been taken over for agriculture. Some of the dense saw-grass marsh areas are now under cultivation and more will be cleared with the progress of reclamation activities. Large areas that were formerly dense saw-grass are now medium dense to sparse saw-grass because many such areas have been drained and burned over and weeds have become common. The wax-myrtle thickets and willow bushes are increasing in many saw-grass areas. Along the border of the Everglades most of the sparse saw-grass areas are changing to wet-prairies. The tree-islands in the slough and tree-island areas are increasing in number and size. Some of the sloughs and ponds with aquatic vegetation are becoming drier and their vegetation is changing to more saw-grass and wax-myrtle thickets. The southern marshes and wet-prairies have changed very little because they have not been drained very much. The bordering prairies are increasing in width as the marshes recede because drainage and cultivation have extended out into the borders of the Everglades from adjoining pinelands, particularly on the eastern side.

All these changing conditions indicate in general that the large saw-grass plains that formerly covered about 1,500,000 acres of the Everglades are shrinking in size as well as in depth of their peat soil. As more and more subsidence of the peat soil takes place and clearing, cultivation, and fires continue and more drainage is devloped, we may expect the prairies, myrtle thickets, and tree-islands to increase at the expense of the saw-grass marshes. If the subsidence of peat soils continues long enough, especially in the shallow areas over rock, then parts of the Everglades will eventually become rockland with only a very sparse marsh or prairie growth.

As a detailed description of the plant life has been published recently in Bulletin No. 25 of the Florida Geological Survey it is not here necessary to describe the vegetation further. There are, however, certain phases of conservation which are closely related to this vegetation which should be considered briefly.

Inasmuch as only a comparatively small part of the Everglades will ever prove practical for agriculture the larger or non-agricultural portion might well be given over to the preservation of natural conditions, especially the native vegetation and wildlife. Of the vegetational areas outlined above those that are most obviously useless for agriculture are the two large slough and tree-island areas where Loxahatchee peat predominates. Other obviously non-agricultural areas are those parts of the saw-grass plains were the organic soils are shallow, most of the southern marshes and wet-prairies, and parts of the bordering prairies that are impractical to drain.

The vegetation and wildlife can hold their own in the slough and tree-island areas if given some encouragement by maintaining higher water levels. In fact, some parts of these sections might well serve as water impounding areas in the development of better water control conditions in the Everglades as a whole. Great parts of the southern marshes and wet-prairies, particularly those areas near the coastal marshes and mangrove swamps, are likewise of little or no agricultural use and some sections of these are now being considered for a National Park. The

scenery, vegetation, and wildlife in some of these areas are very suitable for a park or wildlife sanctuary. Similarly, parts of the saw-grass plains and bordering prairies might serve as recreational and wildlife areas, and as water conservation areas.

Inasmuch as the full details of the exact parts or sections of the Everglades that lend themselves best to recreation, wildlife, park and other conservation purposes cannot be gone into in an abstract of this nature, and since only a small section of the Everglades can ever be considered as satisfactory for agricultural development, we need to plan for that form of over-all conservation which will put the large, unused areas to some use not necessarily related to immediate economic gain but which will contribute to the betterment of life in Southern Florida.

CHAIRMAN MOSSBARGER:

Thank you Dr. Davis. Certainly you have placed before us some very large and important problems which it will be impossible to study intelligently without careful consideration of all these surveys. I hope to live to see the day when we can bring sufficient information of this kind together and get it in proper condition to use in the attainment of the end that you have mentioned. I believe that you are right in your predictions for I feel that every foot of this area has value—tremendous value. As you say, we can't buck nature. We can and must cooperate with her if we are to succeed; and that is our big problem. I believe it is a job that will be accomplished, however, and that is what the work of you men on this program today is leading up to.

I think at this time that the Chair should recognize one of the real "Wheel horses" of this State—a man that has supported this Soil Science Society from the beginning, and one who is very actively interested in the progress reported here today. I know that every man in this room is always glad to hear from the Honorable Nathan Mayo our Commissioner of Agriculture.

COMMISSIONER MAYO:

Mr. Chairman, Ladies and Gentlemen: I always enjoy attending the meetings of the Soil Science Society of Florida. I believe I got more information from the one we had in West Palm Beach last year than from any I have ever attended before; and I know I am going to enjoy this one all the way through.

I first want to bring greetings to you from Governor Holland and the other members of the Cabinet. The Governor was very anxious to attend this meeting, but he is planning for a Governor's conference next week in Tallahassee. Then too, you know, the Legislature will soon be meeting on the hills of Tallahassee, so he has a pretty heavy schedule ahead of him. Nevertheless he asked me to extend to you his greetings as well as those of every other member of his Cabinet. I think one or two of them will roll in this afternoon. Two of them told me they intended to come if they could possibly get here.

I think that holding this meeting at this time here at Belle Glade in the heart of the Everglades is very logical. You know, Belle Glade is a great place. I can remember that I wasn't very popular here in your city a few years back. In fact, it wasn't quite safe for me to wander around alone on the streets. It went further than that on one occasion, purely because of being misquoted. I was called on by a group of men because of that misunderstanding and I probably would have been hanged if they could have found a tree anywhere in this territory with a limb strong enough to support me. Those are bygone days, however, and everything is going along fine. Everyone now greets me with a cordial smile and seems glad to see me. I think this is the right time and place for holding this conference, especially with practically the entire Glades on fire!

I went over to Pompano yesterday to attend a meeting regarding price ceilings and I hope we sold Washington, first, on the idea we don't need a price ceiling, but in the event we do have to have one, that they should give us one that the boys can live on. In fact, my hat's off to that group that made testimony there yesterday. They were good salesmen, and I think the committee from Washington was a very

understanding group. It was very fortunate that we could hold that meeting in the market shed at Pompano as this is the largest single shed in the world. I think the boys got their eyes opened there as to what we were doing in the way of producing vegetables.

As I say, holding this meeting here when the Everglades are on fire is a good thing. Something has got to be done about this and done quick. I was very much reminded as I rode through the area yesterday on my way to Belle Glade, and the smoke was gathering low and it was hard for a car to navigate in places, of a true story that our good friend Frank Williams tells of how when he first started out from college, and he was assigned to Levy County—just a young fellow 23 or 24 years old—and he thought he knew all the angles. Of course he started out at once to do a good job, but while he was rambling around, he saw a negro burning his farm off, and he thought, "Well now here's a good opportunity for me to put in some good work—I'll give that negro a talk and show him how much harm he is doing his soil by burning it." So he stopped and talked to the negro and tried to tell him he ought to plow his land, and he argued around and didn't seem to get very far with him, and finally, he said, "Now look at that land—that land is just as black as you are." The nigger said, "Yessuh, yessuh—thassa fact—that land is just about as black as I is but you come back in about a week, and you'll see that land just about as green as you are!" But we are learning now that it doesn't pay to burn the soil, especially in the Everglades.

You know I well remember the first trip I ever made to the Everglades just about twenty years ago this month. We got out at Okeechobee and came across the lake in a boat—just about the only way you could get around then. There have been wonderful changes made during those twenty years. I only hope I can live twenty more years to see the great changes I know are going to take place in the future.

These Soil Science meetings are very informative, and I truly trust that a program is in the making that will save these Glades from further destruction. We've got the finest land here of any place in the world—we've got an empire here for a home . . . something that nature gave us that it took thousands and thousands of years to build, and it is nothing less than a crying shame to let the soil it took so long to build, go to waste. Something must be done folks, and I want to tell you that if there is anything in the world that the Department of Agriculture can do to help push this program along, we are at your service. This great empire I speak of has potential value which is truly inestimable. These Glades are going to be one of the outstanding areas of agricultural land to be found anywhere in the world. It has a great future for the cattle industry. I see it growing now as more and more cattle are coming in. I can remember the time when cattle didn't do well—they got foot rot and other diseases. Now, however, as you travel around you see vast herds of cattle, and you are going to see those herds increase both in size and in number in the future.

As to the recreational phase of which Dr. Davis just spoke so enthusiastically – the opportunity is truly remarkable; and there is the Everglades National Park which we hope to have soon, using lands which are worthless for agriculture, but of untold value as park land. Then we don't know, we may find oil in these Glades. At least there are good prospects of it. What I am most interested in, however, is to see this vast empire built up to where it will be the outstanding agricultural and live stock section in the world. I am truly glad to be here today.

Chairman Mossbarger:

Thank you Mr. Mayo for your constructive remarks. We are all happy to have you here, especially in view of your broad, invigorating interest in the future of this section of the State. Now there is another man in the audience who is my friend and your friend. He is always keenly interested in anything affecting the Everglades, and we are very happy to have him with us—the Honorable Doyle Carleton.

Mr. Carleton:

Mr. Chairman, Ladies and Gentlemen: I feel something like an intruder—I came here to listen and not to talk. In fact I am reminded of a story about a maiden lady of some forty summers and about fifty winters, who had been waiting on the matrimonial shelf for some time, waiting for a suitable offer of marriage.

Finally she received a satisfactory proposal for marriage, but there was a secret in her life that she hadn't told her sweetheart. She was afraid if she told him he would break off the engagement, and if she waited until later, it might cause a divorce, so she wrote to Dorothy Dix, I believe it was: "My dear Miss Dix—I am engaged to a man I deeply love, but there is a secret in my life that I haven't imparted to him. I am afraid to tell him now, as he might break off our engagement, but if I wait and tell him later, it might cause a divorce. Please advise me what to do under the circumstances. P. S. The secret is that I have false teeth." At once came the reply, "Marry the man and keep your mouth shut."

I have felt since I joined the ranks of the unemployed in 1933, leaving Tallahassee at that time and becoming wedded again to the soil, that I should keep my mouth shut. I am intensely interested in the development work that is going on in the Everglades. I was first introduced to this section in 1916 along with a group of legislators making a tour of the Lake and over this area as far as they could travel; and again at a very sad time following the great disaster of 1926, which initiated our flood control, and which I hope will be of permanent benefit.

Anyone who is interested in this State at all is profoundly interested in this, the richest spot, not only in the state, but in the nation. We are only beginning to realize what can be accomplished. For instance there is the sugar industry, and Mr. Mayo has already suggested oil—I think that is far from a dream and much nearer a reality than most people think. Then there's live stock. We are only just beginning, and I rejoice not only in the possibilities for the future, but in the real progress we are making in solving the problems of the present. Thank you.

Chairman Mossbarger:

Thank you, Mr. Carleton. We are indeed glad to have you here and deeply appreciate this expression of interest and hope for the future.

We will continue the program now by listening to a resume of the work of the Everglades project of the Soil Conservation Service for the past three years and an outline of the program for the future by Mr. C. Kay Davis the Project Leader. Mr. Davis.

SUMMARY OF THREE YEARS OF CONSERVATION WORK IN THE EVERGLADES, AND PLANS FOR THE FUTURE

C. Kay Davis [1]

The underground water investigations, soil and water relationship studies, hydraulic and hydrological observations, engineering, geology, ecology, and soil surveys are all divisions of work that have been in progress during the past three years in the Everglades. The purpose of these investigations and surveys is to determine the most suitable use for every acre of land in the Everglades.

We have progressed sufficiently far with these surveys and investigations now to plan the development of the Everglades according to its physical characteristics. Such a plan will determine the most appropriate use for each section of the Everglades. Every part, every acre, of the Everglades can serve a useful purpose. Any plan that does not provide a useful purpose for every acre of the Everglades will have failed in its accomplishments.

The topographical, geological, and soil surveys indicate that the lands within the Everglades Drainage District may be divided into three general land-use groups, namely: (1) the potentially cultivable lands; (2) the areas that have no immediate agricultural value; and (3) the poorly drained areas of shallow soil which promise only discouragement and failure to those persons who attempt to bring them into production.

The cultivable areas include all the lands which can be made economically productive; fertile lands which are of sufficient depth to justify the investment of water-control systems and facilities and are so situated that mechanical control of the water table is economically feasible and practicable.

The second general land-use classification includes the infertile soils in the mineral areas, and the ridge and slough lands of the organic soils. Only in minor instances has there been any attempt to bring these non-agricultural areas into production. Needless to say, the attempts were complete failures.

There are several small and two large slough areas in the organic soils that offer possibilities as water-storage basins. One of these larger areas is about one-half the size of Lake Okeechobee; the other is fully as large as the Lake. The efficiency of the present canal system can be increased by preventing the continual drainage of these non-agricultural areas into the drainage canals. A part of any funds that may be made available for maintenance and new construction work in the Everglades may well be used for impounding rain waters on these lands. By impounding rain waters in these natural water retention areas, the canals can be made more effective for removing flood waters from their upper reaches.

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[1] Engineer and Project Manager, Soil Conservation Service, U. S. Department of Agriculture, Ft. Lauderdale, Fla. (See also Proceedings, Vol. IV-A, p. 86, 1942.)

The third general land-use classification also consists of lands that are not recommended for agricultural use. The soils in this classification are productive at a price, but the price is all out of proportion to the economic returns. The lands in this classification are so situated or so conditioned by nature that it would be extremely costly or impossible to establish the water control necessary to obtain production of tame grasses and vegetable crops. Either the depth of the soil is too shallow to permit the construction of ditches without rock excavation, or the underlying rock is highly water-bearing, or both. Under extremely favorable conditions a crop may be produced here and there, but more often than not the crop will be damaged or destroyed by drought or flood.

No one objects to the efforts of a property owner to produce a crop on these marginal and sub-marginal lands, except that, invariably, the owner insists upon disrupting the water-table control on the more valuable cultivable lands in order to drain his own. Those who have attempted to control the water table with pumps have failed, because water seeps into the shallow ditches from the underlying water-bearing rock as fast as it is pumped out. These lands are best suited for use as willife and water conservation areas. The production of crops may well be limited to the cultivable lands where conditions are more favorable for the production of agricultural products.

We are now ready to assemble and correlate the information obtained through these investigations and surveys for the preparation of a map which will show the physical characteristics of the three general land-use classifications. Such a map will serve as a guide in correcting the land-use pattern of agriculture in the Everglades. With this information available to those who own property or contemplate investment in the Everglades, we can expect the pattern of ownership to become less complicated and confused.

All of the results obtained from these physical surveys, hydrological investigations and research studies will be made available to the Everglades Drainage District. Putting this information into practice will be a big job and will require the cooperation of everyone whose interest is centered in the Everglades, but it is believed that it can be done.

Chairman Mossbarger:

I am sure we appreciate the words of a man of authority. When he came here, I thought "Well they've sent another one of those things down to tell us what to do with the Everglades." However, Kay certainly has dug in and informed himself from every angle; he has really gotten the feel of this situation and if, as he says, we do not continue this work as it is started now, it will be a catastrophe as far as the future development of the Everglades is concerned. We thank you Kay for those remarks.

The next subject deals with the effect of drainage and other reclamation activities on the rate of subsidence of the land surface in the Everglades. Here again the subject matter is divided and Mr. B. S. Clayton, Drainage Engineer of the Soil Conservation Service stationed at the Everglades Experiment Station will discuss the effect of Drainage and Cultivation. Doctor J. R. Neller will then follow with an analysis of the effect of natural oxidation and crop requirements in terms of water table depths on these trends. Mr. Clayton.

NATURE AND EXTENT OF THE SURFACE SUBSIDENCE OF THE ORGANIC SOILS OF THE EVERGLADES

Part I

Shrinkage and Subsidence Due to Drainage and Cultivation

B. S. CLAYTON [1]

All peat lands, following drainage, lose surface elevation or subside. This loss continues as long as the lands are drained. The Fens of England contain about 300,000 acres of peat some of which have been under pump drainage for more than 100 years. The annual loss of the pumped land is said to be approximately one inch per year. In the San Joaquin-Sacramento Valley of California about 200,000 acres of tule peat has been long in use. Records from that area show a loss of about 2 inches a year, which probably includes some loss from burning. A large portion of the peat in both these areas was originally deeper than that in the Everglades.

The Florida Everglades originally covered about 2,500,000 acres; much of the soil is now very shallow. Of this total it is estimated that only 500,000 to 600,000 acres now has a depth of more than 5 feet. This deep peat is in the northern portion of the area for the most part and is particularly valuable as agricultural land. The deepest portion of this area is on the east side of Lake Okeechobee where depths up to 12 feet are found.

The early subsidence was due to gravity drainage following completion of the large canals about 1914. Drainage by pumping was commenced in 1925. The original elevation of the peat lands for a distance of 6 miles or more from Lake Okeechobee was 20 to 21 feet above the old Punta Rasa datum. The average elevation of much of this land now approximates 15 feet on this same basis. This loss has covered a period of about 30 years. The deep peat area of the northern Everglades now in agricultural use has subsided 4.5 to 5.5 feet and in a few small areas losses of 6 feet have been measured. In such places fires have doubtless caused a substantial part of the loss. The average rate of loss in the cultivated lands during recent years has been approximately one inch per year.

In order to determine these losses accurately a system of reference lines has been established in about 20 locations in the Everglades. The original elevations of the peat lands were taken from the profiles of the large canals. A number of subsidence lines were laid out by the

[1] Drainage Engineer, Soil Conservation Service, U. S. Department of Agriculture stationed at the Everglades Experiment Station, Belle Glade; engaged in water control studies in the peat soils of the Everglades. Formerly connected with irrigation and stream gaging work in Colorado (1909-1915) and drainage surveys in the Mississippi Delta area (1915-1918). Since 1918 Mr. Clayton has been with the U. S. Department of Agriculture on drainage and soil conservation work except for the period 1930-32 which was spent as drainage specialist with the Department of Commerce assisting with the preparation of the drainage volume of the Fifteenth Census.

U. S. Department of Agriculture in 1916 and during the last 10 years a number of additional lines have been established. These lines cover both virgin and cultivated lands and all but one are in the Northern Everglades. At six of the locations continuous records of the water tables have been kept for the past 10 years. At about 5-year intervals levels are run over these lines to determine the change in elevation.

The subsidence loss is due to compaction, slow oxidation from chemical and bacterial action, and some permanent shrinkage of the colloidal portion of the soil. The compaction is due to weathering and cultivation following drainage. The virgin saw-grass soil is of about the same density from top to bottom prior to drainage, but after some 10 years of use the dry weight of the top 18 inches is approximately twice that of the soil beneath. Hence a substantial portion of the total subsidence is a loss in elevation rather than a loss in soil mass.

The continuing and more serious loss is due to natural oxidation doubtless caused in good part by the action of aerobic bacteria. These air-consuming organisms are active only above the water table; hence the higher the water table the less this loss. As the saw-grass lands were flooded or close to saturation most of the time prior to drainage this loss did not occur and there was a very slow increase in the depth of soil.

In reclaiming virgin lands it is of value to know the probable rate of subsidence particularly during the first ten years of use. The available data indicate that a loss of one foot during the first five years; 1.5 foot during the first ten years; and a continuing loss of 1 inch per year thereafter should be expected. Thus after 15 years of drainage and use the loss in elevation would be approximately 2 feet and ditches should be planned accordingly. These figures apply to the lands now being reclaimed along the large canals.

The question arises as to what can be done to decrease the subsidence of these lands. The greatest subsidence in the virgin lands is near the large outlet canals where the water table has been lowered by gravity drainage. Along the North New River Canal the land adjacent to the canal is about two feet lower than that 2 miles back. The former is the more valuable land for development due to its proximity to the canal and the highway. By holding the water high in these canals by means of control dams, which could be closed in dry weather and opened after heavy rains, much of the damage from both fires and subsidence could be avoided.

In the lands more than two miles back from these canals the total loss probably has not averaged more than two feet from the original elevation of the Glades. This slower loss is due to the fact that the gravity drainage was not very effective at that distance from the canal. The continuing loss in these back lands will be very slow — probably not more than a quarter inch per year — hence our primary concern should be to protect the land adjacent to the large canals.

Subsidence in the cultivated land can be reduced appreciably by holding a higher water table. The average depth to water in cultivated land is probably between 2.0 and 2.25 feet. If a depth of 1.5 to 2.0 feet were maintained a substantial reduction in subsidence would be possible.

Several years of records on controlled water tables at the Everglades Experiment Station show the relation of subsidence to depth of water table. The results are as follows:

Water Table Depth	Annual Subsidence
1.0 ft.	0.03 ft.
1.5 ft.	0.06 ft.
2.0 ft.	0.08 ft.
2.5 ft.	0.11 ft.
3.0 ft.	0.14 ft.

These results indicate that below a depth of one-half foot the annual rate of subsidence is directly proportional to the depth of water table.

Some portion of the loss in elevation of the Everglades is due to fires. The greatest damage is adjacent to the large canals where the water table is low in the dry season and the ground is badly cracked. Back a mile or more from these canals it is not probable that fires account for much of the loss except as they destroy potential soil material. Fires can do little damage when the water table is near the surface. The water table in lands adjacent to these canals can be held high during the dry season by means of dams.

All peat land will continue to subside as long as drained and the time will arrive when either the peat is consumed or cultivation shall have to be discontinued on account of the shallow depth of the soil. However, we still have a good depth of soil in most of the agricultural area of the Northern Everglades and with proper attention to the water table the productive life of the land can be substantially extended.

Chairman Mossbarger:

Thank you Mr. Clayton for an interesting exposition even though the insidious downward trends of the land surface which you indicate so clearly are not at all pleasant to contemplate. We will now listen to Doctor Neller's phase of the story. Dr. Neller.

Part II

Natural Oxidation and Crop Requirements as Factors in Soil Losses

J. R. Neller[1]

As pointed out by Mr. Clayton, in the immediately previous discussion, the peat and muck soils of the Everglades are subsiding at an alarming rate.

Investigational work under way is showing that the slow but continual oxidation of our drained peat lands is causing a progressive loss of elevation that is probably greater than that due to any other factor. As already noted by Mr. Clayton, the measurement of soil subsidence lines is showing that the surface of the peat is 4.5 to 5.5 feet lower than it was about 30 years ago when the main canals were dug through the Everglades. Thus, the surface of cultivated areas of this land has been settling at the rate of about an inch a year for the past ten years.

[1] Biochemist-in-Charge, Everglades Experiment Station, Belle Glade. (See also Proceedings, Vol. IV-A, page 9, 1942.)

Experimental work has shown that the amount or rate of this subsidence is directly related to the depth at which the water table is held below the surface of the soil. In other words, before the Everglades were drained the water was near or above the surface most of the time, and the volume of the peat under these conditions was increasing rather than decreasing as at present.

The water table must be kept below the surface, of course, in order to crop the land. Most growers know, however, that the water table in our Everglades soils is often too low for best crop yields. This is being remedied in some instances by better water control installations. Fortunately, improved water control practices which keep the water table in the land from becoming too low also result in diminished soil losses.

Before discussing water table requirement of crops it might be well to point out the relationships existing between water level in the soil and soil loss. Most of these studies were made on an experimental area at the Everglades Experiment Station in which the water table in the land was held at different levels on different plots. These levels varied from 12 to 30 inches. The amount of surface subsidence (in inches) is shown in Figure 1, in comparison with the relative amount of oxidation that occurred for a period of $3\frac{3}{4}$ years (Sept. 1937 to May 1941). It is readily apparent from the trends that are there shown that the loss by natural oxidation and consequent subsidence, was considerably lower in the area where the water table was held at 12 inches below the soil surface than where it was held at 24 inches. Oxidation and subsidence were still greater for the 30 inch water table and somewhat less in an adjacent area where it was periodically raised for a short time and then returned to the 30 inch level.

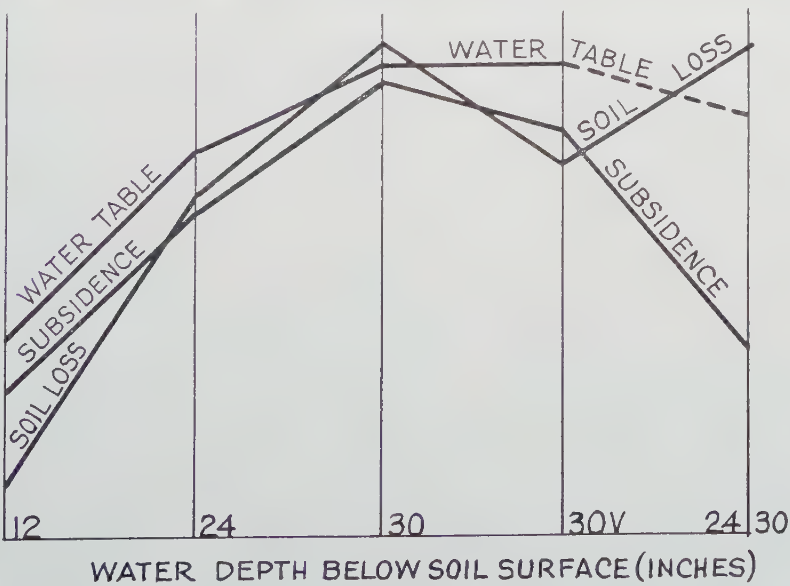

Figure 1.—Effect of depth to water table in Everglades peat on loss of surface elevation through natural oxidation and compaction of soil materials under field conditions.

The last location on the graphs of Figure 1 represents results from an area of Everglades peat which had never been plowed and was still covered with a native growth of sawgrass at the conclusion of these studies. This is outside of an intensively pumped area where the water table in the land has fluctuated considerably with an average of 24 to 30 inches most of the time. It may be noted that soil loss by oxidation in this location was as great as that on the 30 inch water table of the experimental setup but that the subsidence has been much less. This is probably because the land never has been cultivated and the top soil is still loose and fibrous.

When such an area is plowed and cropped the rate of subsidence will be rapid at first. Moreover, some supplementary experiments are beginning to indicate quite strongly that the surface of this unplowed area will subside so much faster that, after a few years of cropping, it will be lower than adjacent areas that have been cropped much longer.

This brings to light a very important principle of land use for Everglades peat soils. This is that lands which have never been broken are in some instances, wasting away at a faster rate than lands that are being cropped. Mr. Clayton's subsidence measurements, as summarized in the preceding paper, show that lands adjacent to and as much as two miles from the canals have subsided considerably more than those farther back. It is evident, therefore, that in an overall plan for better water control which the Everglades needs so badly, provisions should be made for protection of these areas adjacent to the main canals. Moreover, it is probable that this would be one of the first logical developments of such a plan in its relation to the present water control system.

Referring again to Figure 1, it may be seen that there is a striking similarity of the curves of subsidence and of soil loss by oxidation except for the last location plotted. As explained above, the subsidence and soil loss points on these curves will come together after the soil has been cropped. Figure 1 further shows that these two parallel indexes of soil loss are related to and determined by the depth at which the water table is held below the soil surface. In a nutshell, therefore, the conservation of the peat lands of the Everglades depends upon the control of the water table in the soil both on cropped and uncropped areas. The problem for the Everglades as a whole, therefore, is to bring about a more perfect control and utilization of the natural water supply of the region.

As indicated above, most of our Everglades farmers realize the need for better water control for their crops. The systematic water table studies at the Everglades Experiment Station have included investigations by the Agronomists and Truck Crop Horticulturists of the effect of water table levels upon various crops. A brief outline of some of the results of these experiments so far obtained is as follows. The crops divide themselves into four groups — truck crops, pasture grasses, sugarcane and field crops, especially corn.

Much of the cultivated region is given over to truck crops and for these an 18 to 24 inch water table has been found best. Various factors, especially the frequency of rains, modify water table requirements but in general celery does best with approximately an 18 inch level while most of the other vegetables, especially beans and potatoes, grow better when the water level is held at about 24 inches below the surface.

Pasture grasses do well on the 18-inch level though once they are well established some of them will tolerate higher levels quite readily, at least for short periods.

The Sugarcane Agronomist, Mr. F. D. Stevens, has found that some varieties of cane produce best at the higher water tables and some at the lower. Root anchorage and accessibility to the fields need to be considered very carefully in deciding upon the proper water table for a particular time and area.

These experiments are also indicating that corn gives considerably higher yields of grain when the water table is held at the comparatively low level of 24 to 30 inches. Various other crops are being tested and these, as well as those mentioned, will be reported in later publications by the men who are conducting the experiments.

A brief summary of the rather extensive experimental work that has been under way for the past decade shows that natural oxidation in Everglades peat is an important factor in soil losses and that the higher the water table is held in the soil the more the soil is protected against a permanent loss.

Fortunately, good farming and water conservation practices require a higher and more uniformly controlled water table than is now generally maintained in much of the cropped land as well as in the undeveloped areas. While the adoption of better farming practices from the standpoint of water control in the land will help to conserve the lands already in cultivation, there is also an urgent need for a better control and utilization of the waters of the whole region if the thousands of acres in the open glades that have not yet been broken are to be protected.

CHAIRMAN MOSSBARGER:

We thank you Doctor Neller. Your statement is appreciated for we know the authority with which you speak is supported by carefully conducted experiments.

Did I see J. Mark Wilcox back there? With Mark here, I would not feel that the meeting was complete without a word from him. He certainly took his coat off and worked hard enough on many and many occasions toward the betterment of the Everglades, and he couldn't rest until he got himself down in the middle of it, with an interest in agriculture. I'd like at this point to have just a word from you, Mark.

MR. WILCOX:

Mr. Chairman, Ladies and Gentlemen: Like the Irishman that went to the funeral—I just came along for the ride. I came to listen and try to learn. As Mr. Mossbarger says, I've become interested in a practical, personal and financial way in the Everglades recently, proceeding along the lines of the trial and error method. I am trying to improve my knowledge a little by attending this meeting. I don't know what has been said before today, but I followed with interest the Proceedings of the earlier meeting, and have had a great many discussions with Dr. Allison and other men who have been interested in this movement. As a matter of fact I have been interested for a number of years in trying to work out some practical, land use policy for the Everglades.

It seems to me that we have a great many problems that could be solved by systematic application of scientific knowledge. The gentleman who just finished has confirmed in my mind one of the things that Dr. Allison and I have talked about so much in the past. If I understand this chart that has just been discussed, the last figure represents uncultivated land where the water table is very low and, according to that chart, which confirms what I have previously been told, the oxidation or loss of soil is greater in uncultivated land where the water table is very low

than it is in the same land when cultivated where the water is equally low. That is to say the actual loss of soil material is not as great in the cultivated as it is in uncultivated land.

It seems to met that such a finding confirms this thought—that for this total of 500,000 acres of land which Mr. Gallatin says we must look to for the future development of the Everglades we must adopt some sensible and scientific policy of soil and water conservation. Since the only way to do this is by maintaining the highest possible water table at all times in both the used and unused lands this means a setting aside of a portion of them for immediate cultivation or as needed in the near future and turning the balance of them back to what nature intended them for in the first instance and holding them in that condition until such time as they are required for cultivation.

It would appear that the results of indiscriminate and unscientific drainage of the land confirms Dr. Neller's statement that we are rapidly losing the soil in those areas by maintaining a too low water table. It isn't going to be easy to establish a land-use policy because that is going to step on a great many people's toes. In this country we seem to believe that when a man owns a piece of land, he should be able to do whatever he wants to with it whenever he gets ready. The result of that policy is that we are all installing whatever methods we see fit on our own land, without regard to what happens on the other fellows' land. Many people are going to object to any sort of scientific regulation or land use policy for the Everglades, but in the two talks that we have just heard, it seems to me well established that until we do set up some sort of sensible and scientific policy, it is only going to be a very few years until this area we talk about being so fertile and valuable now, is going to be so much waste land. Those of us who have a real and substantial interest in the Everglades must apply ourselves wholeheartedly and sympathetically to the development of a policy towards the conservation and use of the water and the land in the Everglades which will hold this loss to an absolute minimum.

I am glad to be here with you. As I say I came along to listen and not to talk. I don't know anything about the subject, but I am trying to find out. As you know I am intensely interested in it and I want to cooperate in every way that is possible. Thank you a lot.

Chairman Mossbarger:

Thank you Mark for your contribution. You have not only stated the case with characteristic force and clarity but I think you also have put Dr. Allison on his toes to make a better speech on his subject. Dr. Black of the University of Florida, who was to have spoken at this time on the subject of "The Domestic Water Supply Problem in the Everglades and Adjacent Areas" found it impossible to be here. However, his speech will be incorporated in the record of this meeting.[1] So we will now hear from Dr. Allison. As mentioned in my opening remarks, I know of no one who speaks with more authority on the Everglades and on the future use of the land and need of planning. There is no one I know of who has had better opportunity to gain clear insight on that subject, and we will be glad to hear from Dr. Allison at this time on "The Need of the Everglades for a Specific Plan of Development based on the Physical and Chemical Characteristics of its Soils and a Rational Handling of its Natural Water Supply." Dr. Allison.

Dr. Allison:

Mr. Chairman, Ladies and Gentlemen: Inasmuch as Mr. Wilcox has promised that he is not going to talk any more, I should like to take issue with him on one brief but highly irresponsible remark that he made. Otherwise I would keep discretly silent as he is among the very first of all men on this earth that I would prefer to avoid in debate of any kind. Reference is to his statement that he doesn't know anything about the Everglades. In this connection I wish that each one of you could have sat in a hearing called in Washington in 1936 by the Secretary

[1] Inasmuch as a manuscript on this important subject was not made available for publication by Doctor Black, anyone interested in the question of domestic water supply in this section of the State should write him personally in care of the University of Florida, Gainesville.

of Agriculture at Mr. Wilcox's request. That was back in the days while he was so ably representing this District in Congress and before he had retired to the land, so to speak. In any event it was his job, at that time, to sell the then Assistant Secretary of Agriculture. Mr. M. L. Wilson. who presided at the meeting, on the need of the Everglades for a little attention. Mr. Patterson. Mr. Bestor and several others from South Florida were there as well as Dr. Bennett and others from various Bureaus in the Department of Agriculture.

Now the Assistant Secretary had just recovered from a very serious illness and was still quite pale. I know that Mr. Bestor nor any of the others won't soon forget that conference because Mr. Wilcox sat right at the Secretary's side and in a very easy and logical way told him the whole story of the Everglades and its needs in such a clear and concise manner that he gave us a first class case of "Goose-pimples." As a result we got the Everglades Committee of 1936 and 37. So please don't ever, ever, ever let Mr. Wilcox tell you he doesn't know anything about the Everglades!

In closing the discussion for the morning part of the program, I believe that I will read the statement that I have because I am much too liable to forget something I really want to say.

THE NEED OF THE EVERGLADES FOR A SPECIFIC PLAN OF DEVELOPMENT BASED ON THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF ITS SOILS AND A RATIONAL HANDLING OF ITS NATURAL WATER SUPPLY

R. V. ALLISON [1]

The very great need of the Everglades for a specific plan of agricultural development has been acutely obvious for many years. This was made quite clear in a resolution addressed to the Governor and his Cabinet which was passed unanimously at the interim meeting of the Soil Science Society of Florida held last April in West Palm Beach for the discussion of Everglades problems. I now propose to read this resolution from page 131 of the Fourth Proceedings, Volume A, covering that meeting and so re-introduce it into the record.

A RESOLUTION PERTAINING TO THE GREAT NECESSITY FOR A COMPLETE AND UNBIASED INVESTIGATION AND REPORT ON EVERGLADES CONDITIONS WITH SPECIFIC RECOMMENDATIONS FOR ITS USE AS A BASIS FOR A COMPREHENSIVE PLAN OF CONSERVATION AND DEVELOPMENT FOR THE ENTIRE AREA.

WHEREAS, extremely serious conditions pertaining to soil and water conservation of the Everglades Area have been pointed out and discussed in this conference called by the Soil Science Society of Florida in West Palm Beach on this 21st day of April, 1942; and

WHEREAS, conclusive proof has been submitted that great losses of soil and water resources have been sustained in the past from unrestrained and unplanned development and inadequate water control, and can be expected to continue in the future at increasing rates and with more serious consequence to agricultural development and domestic water supplies if existing conditions are not corrected; and

WHEREAS, the permanency of development and future conservation of the Area are threatened by present reclamation processes and agricultural activities which have exploited the organic soils of the Everglades and created serious losses of natural resources; and

WHEREAS, the indicated solution of the related problems concerning the conservation and development of the natural resources of this Area lies in the determination and adoption of an over-all plan of appropriate land use and reclamation; and

WHEREAS, the survey, research and experimental work of various governmental and private agencies during recent years has resulted in an increased knowledge and appreciation for the conservation needs of the Area, and has contributed important data not available at the time past engineering examinations, reviews and reports were made; and

WHEREAS, present existing data have not been fully assembled, analyzed and made available for the information and guidance of those interested or concerned with the problems of the Everglades Area.

NOW, THEREFORE, BE IT RESOLVED that this condition be called to the attention of the Governor of Florida, of the Trustees of the Internal Improvement Fund, of the Board of Commissioners of Everglades Drainage District, and other interested public agencies; praying that relief of present situation be afforded at the earliest possible moment, through the employment of a competent engineering commission, authorized to investigate all existing situations and examine all existing data of

[1] Head, Soils Department, College of Agriculture, University of Florida, Gainesville. (See also Proceedings, Vol. IV-A, p. 34.)

every type relating to the character and use of land; present conditions of tenure and reclamation, including the facilities of Everglades Drainage District, and of its sub-districts; and other reclaimed lands; with definite instructions to prepare a full and complete report on the problems of the Everglades, with specific recommendations for an over-all Plan of Reclamation which will prevent the present wasteful abuses, protect the present development and conserve the large areas of unused lands to the fullest extent.

Be It Further Resolved that a copy of this resolution be sent immediately to the Honorable Spessard L. Holland, Governor of Florida, and to each member of his Cabinet prior to its release to the press and publication in the Fourth Proceedings of the Soil Science Society of Florida.

W. F. Therkildson, *Chairman*
Resolutions Committee
Soil Science Society of Florida

West Palm Beach, Florida
April 21, 1942

During the past two decades innumerable meetings have been held, speeches made and pages written that have touched on this subject from a wide variety of angles. Still, as we examine the situation on this seventeenth day of March, 1943, we must agree that little of a very material nature has been accomplished in the way of developing a comprehensive, fully correlated plan of reclamation and conservation for the whole area. This is best illustrated by the presently wasteful and unplanned handling of its life-blood, the natural water supply, and the steady, progressive destruction of its almost unbelievably productive soils in consequence.

Nothing could more dramatically demonstrate that the above is taking place than a sky filled with acrid smoke from the burning of the soil itself: or vast areas of baking, cracking, organic soils in the undeveloped sections of the Glades that are literally screaming for water and ready to burst into flame at the drop of a match; or the insidious threat of badly contaminated drinking water in our municipal areas of heavy demand; or a wild life population that has fled for lack of natural food supplies in such a man-made desert; or, if I may say so, a searing frost that recently took a painful toll of badly needed food crops throughout the area at a time when these crops should have meant a great deal more to us than the extraordinarily high prices and large profits they would have brought to the individual and to the region.

I bring the question of the February frost, or freeze, if you please, frankly to the front for while none of us can state the exact extent of the loss it imposed on the region in dollars and cents or truly evaluate it from the national defense standpoint, I doubt if there is anyone in this audience who will challenge the statement that this blow would have been very appreciably reduced, and even obviated in some parts of the area, if the open Everglades had not been so exceedingly dry. By way of amplifying this point I would call your attention to the fact that in March of 1932, when the glades was very dry, due in part to construction work on the levee, a temperature of 9° F. was measured in an open, undeveloped section at a point about 12 miles from the Lake. At this same time there was only a light frost at the Everglades Experiment Station, in the midst of a developed area. At another time, however, when the water at the same point in the open glades was high (well above the

surface) there was no frost on a comparatively small area of adjacent, cultivated land which, under those conditions enjoyed the status of a small island, whereas, at this same time, there was a frost at the Everglades Station located within a larger, drained and cultivated area. I mention these physical relationships only because of their very great economic significance.

So much for the pessimistic side, for I am glad to say that some real progress of a kind has been made in the direction of developing a specific plan for the Everglades. This, first of all, is in the nature of an aroused public interest in and concern for what is going on. No one possibly could have sat in the meeting held in West Palm Beach last April and witnessed the intense interest expressed in every phase of the physical and economic problems that were there so comprehensively discussed without feeling confident of this. In other words the immunity to analyses and planning the Everglades seems to have enjoyed for so many years, appears at last to have been broken largely, I suspect, through the discovery that while the area is quite monstrous in a geographical sense, the fundamental principles upon which the solution of the main problems must be based are quite simple. Paramount among them is, of course, water conservation and control.

Any plan of conservation and development for the Everglades that is to be at once sufficiently broad and specific to coordinate all aspects of the many problems that present themselves must include, among others, the following considerations:

1. An orientation of permanent water reserve areas based (a) on their location in relation to the water requirements of the whole area including the proposed Everglades National Park and (b) the agricultural potentialities of the lands to be involved in these reserves.

2. A zoning of lands presently classed as agricultural by modern survey methods in such a way that a unit plan of reclamation can be developed for those not required as permanent water reserves, with a full acknowledgment of the limitations imposed by developments already under way.

3. A systematization of lake control with the view of extending the use of this great reservoir for water storage just as far as possible.

4. Continuation of intensive surface and ground water studies over the entire Everglades area, including all tributary drainages, as the only reliable source of basic, hydrologic data on the character and control of the regional water supply that are so essential for sound planning in a low-lying, flatland area of this type.

5. Continuation of research and investigation of all types into the movement of water over and through Everglades soils, and their supporting substrata as a basis for detailed planning of water control in all sections of the area.

Thus one of the first and most elementary necessities in the development of any plan, whatsoever, for the Everglades is a clear segregation of presently cultivated and uncultivated areas by proper boundary dikes. For if we are to flood the so-called open glades, whether as permanent water reserves on the extensive, non-agricultural lands in the central and Lower Glades or great areas of undeveloped agricultural lands that lay

out there but which in the meantime must be protected, we must have boundary dikes to hold this water off of adjacent, cultivated areas. Somewhere there must be well-planned and well-constructed retaining barriers, for flood waters will not be restrained either by pretty phrases or others that are not so pretty. This is the only way we will ever get away from the too popular idea that water is an enemy—that is when we happen to have a bit too much of it in the wrong place. I believe it has been fully demonstrated in the Everglades that deficiencies of water may do much greater and more permanent damage than excesses. Such physical lines of demarcation between presently cultivated and uncultivated lands must be decided upon as are locally satisfactory to the owners of the land and to the community. Furthermore, these local decisions must be of such a nature that they will join smoothly into a unified pattern for the whole region. This, of course, cannot possibly be accomplished without much careful planning and appropriate conferences with and among those immediately concerned.

Now, if we are to be really realistic in the consideration of this question of the need for a specific plan of development for the Everglades, I feel we should review it rather definitely from at least two additional angles, namely:

(1) Upon what data it is to be based and,

(2) By what Agency and in what manner it is to be developed and administered.

With respect to the first question, it is generally agreed that there is quite a large amount of scientific and engineering data available in widely distributed files that should find a very definite place in the organization of such a plan. This accumulation represents a long period of effort on the part of Federal, State and local agencies, that are research and extension as well as operational in character, but it will represent little more than a waste of public money unless it is carefully analyzed and put to real use in the development of such a plan for the area. As a matter of fact this is its real purpose.

While such a study may reveal striking deficiencies in the data that might have been obviated if they had been developed with a little closer harmony and understanding of purpose among the agencies involved, perhaps we can still find benefit in such deficiencies and disharmonies if they can be made to serve as a stimulus for a more thorough coordination of the work in the future. This is an objective that could well become a part of the plan of operation itself since that plan, whenever or by whomever it is developed, will be no stronger than the information and understanding upon which it is based and the manner in which it is administered.

And that brings us around to the second point, which, like either the hen or the egg, could as well have been first in any discussion involving both.

Personally, I feel very firmly that it has been the almost complete lack of a strongly centralized, over-all authority in the Everglades Drainage District with adequate means for the accomplishment of this important task of coordination among agencies and planning for the future that has been responsible for the winding trail and rather diverse paths

we have followed in the past. With such an authority available for consultation and guidance the result could, should, and, I am sure. would be much different.

Just as the construction of the great dike about Lake Okeechobee has opened up new potentialities of water control for the whole Everglades project, though, as yet, it has not come into any very extensive use in this capacity, so has the refinancing of the Everglades Drainage District introduced a new era in the financial welfare of the whole organization. And this is where the means wherewith to plan and to implement those plans comes in. To my way of thinking the first thing the Everglades Drainage Board must do is realize that it has on its hands a $50.000.000, or a $100,000,000, or a $500,000,000 project, depending upon the imagination and understanding of the estimator, for which it has about the same responsibility as a mother to her child. Now let us start from there and see what we can find in the way of a summarization of the situation.

I have discussed briefly the wholly obvious needs of the Everglades Drainage District for a specific plan of development and have fortified this need by reading a resolution dealing with this subject that was passed unanimously at a meeting of the Society held in West Palm Beach last spring.

I have mentioned some of the outstanding features of such a plan with particular emphasis, of course, on the all-important principal of water conservation and control.

I have called attention to the fact that a number of agencies. Federal, State and local have been engaged for several years on various phases of the Everglades problems though not always with as full coordination of their efforts as might be the case if there were a central authority responsible for such coordination and use of these data for planning; and that these agencies are continuing industriously upon these projects.

I have pointed out that the existence of such a central authority is as important as the plan itself in view of the fact that it should have the full responsibility for coordinating the collection of data to be used in such a plan as well as ordering the development of that plan at the proper time.

Finally. I have suggested that the masterly refinancing of the Everglades Drainage District, so recently accomplished by Governor Holland and his co-workers, opens up a new era of opportunity in that a normal income has been restored to the district from the collection of taxes on the land.

In view of all this I now recommend for the favorable consideration of the Society the preparation of a further resolution commending the Everglades Drainage Board for its whole-hearted and far-sighted cooperation with the Governor and his Cabinet in reestablishing the financial well-being of the District and recommending that the Board now study and develop all authority with which it is provided under the law with the view of establishing itself as a CENTRAL AUTHORITY in the District. It is moved, therefore, that such a resolution be drawn by the Resolutions Committee, and that there also be incorporated in it the recommendation that the Everglades Drainage Board feel free to adopt the Soil and Water Conservation Committee of the Soil Science Society of Florida as an Advisory

Committee if it feels that this might prove helpful to its work in any way: and that a copy of this resolution be transmitted by the Secretary of the Society to the Governor and to each member of his Cabinet and to the Chairman and to each member of the Board of Commissioners of the Everglades Drainage District prior to its release to the press and publication in the Fifth Proceedings of the Society.

CHAIRMAN MOSSBARGER:
Thank you, Dr. Allison—

COMMISSIONER MAYO:
Mr. Chairman: We had a fine meeting over at West Palm Beach a year ago. We are having a fine meeting here today—it's a crackerjack, but I think that the time has come to get down to business. I am going to make this suggestion. The Legislature is going to meet now very shortly. However, I am confident there is still time to make plans and get something done before it adjourns. I would suggest, and I am making it in the order of a motion, that we have a joint meeting of the Everglades Drainage Board, the Okeechobee Flood Control Board, the Fire Control Board, the National Park Service and other organizations and individuals interested in the work with the Internal Improvement Board at the earliest possible date and also have at this meeting these scientists, both State and Federal. I think this matter is of such importance that we ought to get busy and do something at once. The soil is sinking every year, more and more, and each year more and more of it is burning up. We've got an asset here in the Glades that we must pay attention to. It is too valuable. So I am making the motion that we have an amendment to the resolution proposed by Dr. Allison to the effect that a joint meeting of those institutions and individuals I have just named be held at the earliest possible date to see if we can work out a plan for the Legislature to put before the Federal Government, which I understand is ready to help us to lay out this plan both financially and otherwise. Now I don't see why we can't get busy and get some action:

CHAIRMAN MOSSBARGER:
You have heard Mr. Mayo's motion that the proposed resolution be amended and the nature of the amendment — is there a second?

R. Y. CREECH:
I second the motion.

CHAIRMAN MOSSBARGER:
Is there any discussion of the motion?

W. TURNER WALLACE:
Where is the meeting to be held?

COMMISSIONER MAYO:
In Tallahassee, I would think.

MR. WILCOX:
I'd like to ask Dr. Allison—you have in mind some very definite legislative program along that line, do you not?

DR. ALLISON:
I believe you ought to ask Mr. Turner Wallis that question.

Mr. Wilcox:

I know you have some very definite ideas as to conservation but is it your thought that there should be additional legislation, if time can be found to work it out; do you have it pretty well blocked out as to what it would take?

Dr. Allison:

While additional legislation may be necessary it is obvious that existing laws should be examined very carefully by those who are competent to do so before deciding this point. Answering your question more directly, I certainly have not undertaken to draw up anything in the way of a legislative plan, personally, as that is a rather too far cry from the theory and practice of Soil Science. As I said before, Mr. Wallis should speak on that point. It is obvious, however, from the discussion that has taken place today that at such time as the matter *IS* considered, very full and careful attention should be given to the determination of what is required to bring about that centralization of authority in the District which is so vital to the development of an efficient and effective reclamation and conservation program in the future.

Chairman Mossbarger:

Just to clarify this point we have various boards represented today that will go into session in the near future and have a full discussion of this phase of the subject. I think this resolution should be drawn with the understanding that it must meet their full approval when and as they get to their discussion of these problems. I'd like to see this resolution passed, subject to the action and approval of these groups and place the Soil Science Society at the service of those that have to do with the actual carrying out of various plans throughout the Everglades, because only when we do that and get a unanimous support behind some definite objective, have we made progress.

Mr. Orrin Randolph:

If you will excuse me for encroaching on the meeting—even in 1936 and 1937 we had a group down here from the Department of Agriculture, making a survey, but the trouble then and always has been that we dealt in generalities with everybody acknowledging that there should be a land use policy, and that there should be a water control policy. While we are all agreed, we never do anything about it, never actually get down to the development of a concrete plan to be adopted and put in effect. I think Mr. Mayo's suggestion is most timely—to get all these agencies together with the I. I. Board on the eve of the convening of the legislature and get a definite plan worked out to secure whatever legislative authority is necessary to put it into effect. Up to this time, energetic people like Dr. Allison and these other scientists keep working and pegging away, have these meetings, get us all enthused and that winds the thing up and nothing has been done. Now we have a definite job to do, and I think this resolution and the amendment by Commissioner Mayo is the most timely suggestion that has been made in the whole discussion.

Chairman Mossbarger:

Thank you Mr. Randolph, for your remarks. Naturally it has been our hope that out of this meeting would come that thing you are talking about. As you say, the resolution Mr. Mayo has amended is timely, and by all means should be passed. I am sure the various groups that have been mentioned will cooperate fully in an effort of this nature. If there is no further discussion, we will take a vote.

The vote was unanimous.

Chairman Mossbarger:

That winds up the program of the morning. Now that plan that Mark Wilcox and Mr. Mayo are so earnestly concerned about will have ample opportunity for discussion right here, because we have these various agencies represented and a program prepared for the afternoon that has much to do with that very thing. I take pleasure at this time in turning the afternoon program over to Mr. W. Turner Wallis, a man who has probably traveled more miles and done more work in the Everglades than any one man in the state or out. Mr. W. Turner Wallis.

PROBLEMS AND ACCOMPLISHMENTS OF ADMINISTRATIVE AGENCIES CONCERNED WITH THE CONSERVATION AND USE OF EVERGLADES LAND

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AFTERNOON CONFERENCE — MARCH 17, 1943
2:30 P. M.

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INTRODUCTION

W. TURNER WALLIS, Chairman [1]

CHAIRMAN WALLIS:

The meeting will now come to order as we have a considerable amount of ground to cover in order to get through here in time to get to Clewiston for dinner and the evening meeting.

We will now hear from various members on the "Problems and Accomplishments of Administrative Agencies Concerned with the Conservation and Use of Everglades Soils." The first speaker is Mr. Ben Herr, Executive Secretary, Okeechobee Flood Control Board, West Palm Beach. Mr. Herr.

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[1] Chairman, Soil and Water Conservation Committee, Soil Science Society of Florida, West Palm Beach. (See also Proceedings, Volume IV-A, p. 113, 1942.)

CALOOSAHATCHEE RIVER AND LAKE OKEECHOBEE DRAINAGE AREAS, FLORIDA

Ben Herr [1]

The creation of the Okeechobee Flood Control District by the 1929 Legislature of Florida was one of the more direct results of the tragedies of 1926 and 1928 when hurricanes swept across the Lake Okeechobee area resulting in the drowning of some three thousand persons and the destruction of millions of dollars worth of property. In order to set forth completely and in detail the part which the District has played in the development of the Everglades, it is desirable to present a short review of the history of the attempts made to control Lake Okeechobee in connection with the reclamation of the Everglades.

Lake Okeechobee lying at the north end of the Everglades was originally a land locked body of water serving as the reservoir for a drainage basin of some 4,500 square miles and having no natural outlet except through overflow over the southern shores of the Lake into the Everglades. The Lake has an area of 700 square miles and is extremely shallow with the bottom of the Lake at the deepest part being at sea level. The main tributary of the Lake is the Kissimmee River which enters the Lake at the north-west corner and has its headwaters in Lake Kissimmee lying some 60 miles north of Lake Okeechobee.

The average rainfall over this area is 54 inches per year and the major part of the rainfall occurs from June to November. An additional important fact is that this rather heavy annual rainfall is apt to include one or more storms during the rainy season of 10 to 20 inches of rainfall within 48 hours. Reviewed briefly the facts surrounding the original conditions are as follows:

1. Lake Okeechobee was originally a land locked body of water with no natural outlet.
2. Lake Okeechobee is a large but shallow body of water which is the reservoir for a large drainage basin of some 4,500 square miles.
3. The Lake Okeechobee area has an annual rainfall averaging 54 inches largely concentrated in the summer months and apt to include extreme storm conditions.
4. The natural south shore of the lake is low, now averaging about 17 feet above sea level.
5. The elevation of the water in Lake Okeechobee originally varied from 15 to 21 feet above sea level.

The natural result was that except in extremely dry years the Lake overflowed the south shore and kept the Everglades flooded the greater part of the year.

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[1] Engineer, Okeechobee Flood Control District, 1929 to date and Secretary since 1937. Mr. Herr is a native of Kansas City, Missouri and a graduate of the University of Illinois, 1925, with a B.S. in General Engineering. From 1925 to 1929 he was employed by Carter and Damerow on drainage, irrigation and highway work in Indian River County. He also served as Secretary of the Everglades Drainage District from June, 1931 to November, 1934.

When drainage work was begun in the Everglades the region was almost inaccessible and little accurate knowledge was available on the physical facts. The theory was pursued for some years that a number of openings through the sand ridge along the borders of the Everglades to provide outlets to the sea would afford sufficient drainage to develop the entire area. Experience and knowledge gained as the work progressed soon developed the fact that the first essential for the reclamation of the area was the control of the waters of Lake Okeechobee.

Although a connection had been effected between the Lake and the Gulf of Mexico as early as 1890 through the efforts of the Disston interests in constructing a small canal connecting the south-west corner of the Lake with the headwaters of the Caloosahatchee River, the purpose of this canal was to provide a means of communication by small boats with the area lying north of Lake Okeechobee and was of no practical value in controlling the level of the Lake. Later as the several canals constructed by Everglades Drainage District formed outlets to the Atlantic Ocean it was found that these canals were taxed to capacity by the needs of drainage of water from the land and afforded no relief for Lake control.

As early as 1913 it was recognized that a large independent outlet was necessary for the sole purpose of controlling the level of Lake Okeechobee and surveys for a location for such a canal were begun shortly thereafter. After several years of survey and study the decision was made to construct an outlet canal from the east side of the Lake to the headwaters of the south fork of the St. Lucie River about ten miles west of Stuart, Florida. This location passed through some comparatively high land but it was found to provide the greatest drop in the shortest distance and to be the least expensive.

Accordingly, the St. Lucie Canal was constructed by Everglades Drainage District at a cost of $6,000,000.00. The Canal is 25 miles long and varies from 150 to 200 feet in bottom width. It has a capacity of discharge of 5,000 second feet from Lake Okeechobee with the Lake at elevation 17 feet above sea level and it has a navigable depth of 10 feet with pool elevation of 16 feet above sea level, although the sills of two locks in the canal, one at either end, restrict the navigable depth at present to 6 feet. With the completion of this canal in 1924, there was afforded for the first time not only a means of direct control of the level of Lake Okeechobee but a continuous waterway across Florida from the Atlantic Ocean to the Gulf of Mexico.

The development work carried on during all of this period resulted in an accumulation of information and data that caused a revision of the ideas and plans for reclamation from time to time. By the year 1920 the accumulated hydrological data together with the experience gained from agricultural attempts disclosed that the completion of the St. Lucie Canal would not in itself provide the complete control necessary over Lake Okeechobee to give adequate protection to farming operations at all times. It was learned that in the rainy season and under the influence of sudden and heavy storms the Lake level would rise much faster for a short time than it could be controlled by the outlet canal so that the adjacent land was still apt to be flooded for weeks at a time so

that no farming activities could be carried on successfully. It was also determined that there existed the possibility of floods occurring from the influence of heavy wind storms on the water of the Lake.

There was no reliable data available on the actual effect of a storm of hurricane proportions on the Lake and the adjacent land but in 1922 the Everglades Drainage District started the construction of levees along the lower portions of the south shore of the Lake providing general protection against a Lake elevation of 22 to 24 feet above sea level. The levees built were small and of varying heights constructed from the material available which in some cases was shell and rock but in others it was only muck.

The conclusions reached for the need of the levees were fully justified in September 1926 when a hurricane crossed the State of Florida, passing just south of Lake Okeechobee. Unfortunately, the levees constructed by that time were neither large enough, high enough nor strong enough to provide any adequate protection against the actual conditions which obtained. The high winds swept the waters of the Lake over the levees and over the land on the south side of the Lake causing the loss of thousands of dollars in property damage and resulting in the loss of over 400 lives by drowning in the vicinity of Moore Haven on the southwestern side of the Lake. The direction of the wind was such that the greatest effect was felt at Moore Haven but great damage resulted throughout the region.

After this storm the levees were replaced temporarily and plans were formulated for the construction of levees of a size that would be sufficient to provide protection against conditions experienced during the 1926 storm. Because of financial and other difficulties no work was done immediately and in September, 1928, the region was again visited by a hurricane which crossed the center of the Lake in a north-west direction. The loss from this storm was immensely greater than from the 1926 storm. The wind direction was such as to cause the greatest loss around the southeastern shore of the Lake where the greatest development as of that date had taken place. The levees were overtopped and the land flooded to a depth of about 8 feet, resulting in the tragic loss of 2,000 lives by drowning and in the destruction of almost all of the improvements on the Lake shore between Pahokee and Lake Harbor. The American Red Cross rushed to the relief of the area and expended over two million dollars in providing food, clothing and shelter, and in rebuilding many homes that had been destroyed.

These two disasters occurring within two years would undoubtedly have resulted in the abandonment of any further attempts to reclaim and develop the Everglades if it had not been for the universal recognition of the intrinsic value and the tremendous potentialities of the land. With the reclamation work not yet completed and with only a few years of actual farming experience the richness of the region was so well recognized that the residents and landowners were willing to undergo many hardships and make every effort to overcome the handicaps under which they labored and the disasters which had occurred.

Following the storm of 1926 an attempt was made to interest the Federal government in the reclamation of the area and particularly in providing protection against such storms as had occurred. The first

result of that effort was the submission of a report by the War Department to Congress which was printed as Document No. 215, 70th Congress, 1st session, House of Representatives, dated April 7, 1928. Before any action was taken the 1928 storm occurred and a review of the previous report was requested. This review was presented by the War Department on January 31, 1929, and was printed as Senate Document No. 213, 70th Congress, 2nd session.

In April, 1929, the Legislature of Florida convened and its aid was immediately requested in seeking a solution of the problem of providing protection for the Everglades Area. That body recognized that the problems of flood control and navigation raised by the storms of 1926 and 1928 were of great magnitude and beyond the scope of the problems of drainage which were the responsibility of the Everglades Drainage District.

As a result of their deliberations, Chapter 13711, Acts of 1929, Laws of Florida, was passed, creating the Okeechobee Flood Control District for the express purpose of providing protection to life and property against the flood waters of Lake Okeechobee, the Caloosahatchee River and vicinity. That District is now in existence under authority of Chapter 14777, Laws of Florida, Acts of 1931, which recreated the District, as amended by Chapter 16090, Acts of 1935, and as amended by Chapter 18039, Acts of 1937. It has no responsibility, duties or authority over matters of drainage problems, all of which remain with the Everglades Drainage District.

Following the creation of the Flood Control District, efforts were renewed and intensified to interest the Federal Government in the problem of providing protection to the Everglades area. For many years the dream of a waterway across Florida by way of the Everglades had persisted. It was suggested and recommended in Congress prior to 1850 and at numerous times thereafter many persons and organizations had made efforts to bring about the construction of such a waterway. Although sympathetic at times, until 1930 the Congress had never acknowledged that the Federal Government had an interest in the Everglades or that potential navigation in that area warranted any Federal expenditures. The cost of the inadequate waterway provided across the State by the completion of the St. Lucie Canal had been borne by local interests as had all of the cost of reclamation in the Everglades.

In renewing the efforts to interest the Federal Government in this problem, the Flood Control District presented a report to the War Department and to Congress which was printed as Senate Document No. 225, 71st Congress, 3rd session. The report was very comprehensive in nature. It recited in detail the history of the Everglades area and gave an elaborate factual story of the development of the natural resources of that area within a period of a comparatively few years. The report explained the need for flood control and expounded the interest of the entire nation in providing such protection.

This document gave equally as complete attention and consideration to the problems and needs of navigation. It set forth fully the long struggle for a cross state waterway and the final accomplishment of that fact to a limited extent. It brought out the fact that such a waterway

was commercially feasible and that it had been gradually developed by private interests at a cost of millions of dollars without the assistance of either Federal or State funds although navigation improvements are normally a function of the Federal Government. The report asked that the United States recognize the navigation feature as a Federal project and requested that the waterway available at that time be improved sufficiently to meet the growing needs of water transportation for the area. It asked further that in connection with the navigation feature the United States recognize the need for flood control and harmonize the two problems so that both would be solved by the adoption of the same project.

An Act to adopt this project by the United States was introduced in Congress in December, 1929, and was referred to the Flood Control Committee of the House of Representatives, later being referred to the Rivers and Harbors Committee. Numerous hearings were held from December 1929 to April 1930 before both of these Committees and before the Committee on Commerce of the United States Senate. Many representatives of the State Government and of local interests appeared before these committees and gave evidence of the need for the work. After lengthy deliberations the Congress decided to adopt the project as a navigation feature with due consideration to be given flood control in carrying out the project and it was so included in the Rivers and Harbors Act signed by the President on July 3, 1930.

The project was adopted in the Rivers and Harbors Act in accordance with the report of the War Department, printed as Senate Document No. 115, 71st Congress, 2nd session, with one exception. That report recommended the following improvements and conditions:

(a) For improving the Caloosahatchee River and Canal from Lake Okeechobee to the Gulf of Mexico by straightening and by dredging a channel which will provide a discharge outlet capacity of 2,500 cubic feet per second from Lake Okeechobee, and a navigation channel at least 6 feet deep and 80 feet wide, including the necessary control works	$1,557,000.00
(b) For improving Taylor Creek by providing a channel 6 feet deep and 60 feet wide from Okeechobee City to Lake Okeechobee	58,000.00
(c) For a levee and navigation channel 6 feet deep and 80 feet wide following in general the south shore of the Lake	6,663,000.00
(d) For a levee on the north shore of the Lake	1,214,000.00
(e) For improving the St. Lucie River to provide a channel 6 feet deep and 80 feet wide	25,000.00
(f) For protection works in St. Lucie Canal	175,000.00
Total estimated cost	$9,692,000.00

and provided that all levees shall be subject to modifications of location and design at the discretion of the Chief of Engineers; that the State of Florida or other local interests shall contribute $3,812,000.00 toward the cost of the above improvements, furnish evidence satisfactory to the Secretary of War that they will construct the north shore levee to a design to be approved by the Chief of Engineers, estimated to cost $1,214,000.00; provide all lands needed for levees, channels and the disposal of spoil; agree to maintain all works and channels within the limits of Everglades Drainage District and to charge no tolls on any of these navigable water-

ways: agree that whenever authorized by Congress, the United States shall have the right to modify or improve any of these waterways and their appurtenant structures; and that the St. Lucie Canal, the Caloosahatchee Canal and other channels forming the proposed cross-state waterway shall be navigable waters of the United States and subject to the Federal laws for the protection of such waterways.

In adopting the project in 1930, the Congress approved the program of work outlined but required the United States to perform the work of constructing all levees: provided that the State of Florida or other local interests, should contribute $2,000,000.00 toward the cost in lieu of the contributions called for in Document 115; and provided that no expense should be incurred by the United States for the acquirement of any lands necessary for the purpose of the improvement. The wording of the Act was interpreted to mean that local interests were not required to construct the north shore leeve and were required to pay $2,000,000.00 toward the cost of the project instead of $3,813,000.00 but were obliged to fulfill in toto all other obligations recommended to be met by local interests in Document No. 115.

On October 22, 1930, the Okeechobee Flood Control District by a formal resolution constituting a contract between the District and the United States, agreed to assume the obligations laid upon local interests by the provisions of the Act, under authority of the laws of Florida creating the District, and prescribed a general program of meeting those obligations. Accepting this resolution as compliance with the provisions of the Rivers and Harbors Act, the War Department started work upon the project in November, 1930.

The project was amended by the Rivers and Harbors Act of 1935 which contained the following paragraph:

> Caloosahatchee River and Lake Okeechobee Drainage Areas, Florida: The existing project is hereby modified to provide that the United States shall maintain all project works when completed and shall bear the cost of all drainage structures heretofore or hereafter constructed in connection with said project: Provided, that the total cash contribution required of local interests toward the cost of the project shall be $500,000.00.

As the Okeechobee Flood Control District had paid the sum of $500,000.00 to the United States in cash prior to the passage of the 1935 Rivers and Harbors Act the District was relieved of any further obligation for cash payments or maintenance with respect to the project.

In 1937, the project was again amended by the Rivers and Harbors Act of that year which included the following paragraph:

> Caloosahatchee River and Lake Okeechobee Drainage Areas, Florida: Rivers and Harbors Committee Document Numbered 28, Seventy-fifth Congress;

The designated document was a report by the War Department recommending the construction of a new lock in the St. Lucie Canal to replace the present locks 1 and 2 at an estimated cost of $806,000.00 providing that local interests furnish all lands and easements necessary for the execution of the work.

The original construction program has now been completed by the United States. The levees were completed early in 1937 and the waterway

from Stuart to Fort Myers was officially opened and placed in operation on March 22, 1937.

Additional construction work has been done since that time and is still in progress. In 1938 serious erosion developed in the levee along the east shore of the Lake between Port Mayaca and Bacom Point and this portion of the levee was reconstructed. The section was greatly enlarged and the top elevation was raised four feet. The Lake side surface of the levee was paved for some miles with various types of paving including concrete, rock, asphalt, and soil cement treatment.

Subsequently the lock and spillway authorized in 1937 was undertaken and the lock at the east end of the St. Lucie Canal is now in use. The spillway is completed except for the placing of the gates and operating machinery. These will not be installed until after the war because of the shortage of steel for their construction. In the meantime, temporary needles have been installed for use in operation of the spillway.

As a result of this project, there is now a levee around both the north and south shores of Lake Okeechobee which prevents the overflow of any water from Lake Okeechobee on to the adjacent low land, particularly the Everglades proper around the south shore, under either normal or abnormal conditions. The Levee has a minimum height of 20 feet above ordinary lake levels which is sufficient to prevent the flow of water out of the Lake under the influence of more severe hurricanes than any of which we have record.

The drainage outlets from the land into the Lake have been preserved and protected by the construction of hurricane gates and culverts. These structures permit the passage of water either into or out of the Lake under permanent control. Thus the land can be protected from the flow of water out of the lake during periods of high water and during dry periods the flow out of the Lake on to the land can be regulated as desired, or as the Lake level permits. The control of the waters of Lake Okeechobee which was found to be necessary as early as 1920 has thus been completely provided.

There is also a completely usable navigation canal connecting the Atlantic Ocean and the Gulf of Mexico. The limiting dimensions of this canal are a minimum depth of 7 feet, minimum width of 50 feet at the bridges and locks and a minimum overhead clearance of 52 feet at the F. E. C. railroad bridge at Port Mayaca. The canals permit the gravity discharge of water from Lake Okeechobee to the Atlantic and Gulf under complete control thus adding to the measure of control over the level of Lake Okeechobee.

A tabulated description of the physical components of this project is attached hereto.

In January, 1939, the Rivers and Harbors Committee of the House of Representatives, U. S. Congress, adopted the following resolution:

> Resolved, by the Committee on Rivers and Harbors, of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors created under section 3 of the Rivers and Harbors Act, approved June 13, 1902, be and is hereby, requested to review the reports on the Caloosahatchee River and Lake Okeechobee Drainage Areas, Florida, submitted in Rivers and Harbors Committee document numbered 28, 75th Congress, 1st session, in Senate document numbered 115, 71st Congress, 2nd

session, and previous reports, with a view to determine if the existing project should be modified in any way at the present time.

Pursuant to this resolution the U. S. District Engineer, Jacksonville, Florida, prepared a complete and comprehensive report of the Lake Okeechobee project. Work on this report went on for three and one-half years and the report was finally completed in November, 1942. It has not yet been submitted to Congress so it is not available in published form but it may be examined at the office of the District Engineer, Jacksonville, by any interested party. Because of War Department regulations, direct quotations cannot be made from this report until it has been submitted to Congress.

In preparing this report the War Department interpreted literally the direction of Congress to review all the reports on this project. The Department made exhaustive studies not only of the hydraulics of the control of the Lake itself but of its connection with and effect upon the reclamation of the whole Everglades area. Studies were made of the effect of the Lake Control on land drainage and irrigation, farming activities, soil subsidence, fire control, domestic water supply, and all related subjects. When the report was finally completed, much of this subject matter was omitted but reference is made in the report to some conclusions with regard thereto, and the mass of data assembled is available in the U. S. Engineer office.

One of the main points to which reference is made in this report and to which reference has been made numerous times by the U. S. Engineers while working upon the report is the lack of a comprehensive drainage plan for the Everglades. The United States has expended to date approximately Twenty Million dollars on the Lake Okeechobee project and has established permanent offices in the area. The War Department has been given and has accepted a definite responsibility with regard to the control of Lake Okeechobee and it has taken a keen interest in the development of the Glades area. It may be said that one reason that such interest has not been expanded further into concrete action is due to the divided responsibility between various agencies working in the area, the lack of any one authority with whom the War Department might cooperate on some basis and the lack of any definite plan of operation for the reclamation of the Glades into which the War Department might fit its activities.

This has been evident on any number of occasions but one specific instance occurred when the War Department was ready and willing to do some maintenance work in the main canals of the Everglades Drainage District by the removal of hyacinths and perhaps of some obstructions. The work was not carried out completely because the War Department was unable to make any definite commitment with any responsible agency and was unable to locate any plan of operation which they might properly follow in carrying out the work they were ready to do.

Reference is made to these matters in connection with the Okeechobee Flood Control District for the reason that the District is the official agency which has a definite contract with the United States to cooperate with the War Department on the Lake Okeechobee project in perpetuity. The War Department has expended some Twenty Million dollars in the

Everglades and has completely provided the one essential which was recognized as early as 1920 as being absolutely necessary to any reclamation: i. e., the complete control of the waters of Lake Okeechobee. Because of that expenditure and that work, the War Department has a definite interest in the area and has evinced its willingness any number of times to cooperate with responsible agencies so far as the law provides.

The Flood Control District has authority extending only to the control of Lake Okeechobee but it is the representative of the local landowners and residents and its interest lies in seeing that the work that has been accomplished to date is used to the fullest extent in further development in the area.

As a matter of interest and information with regard to the District, the operations of the District have always been on a cash basis. No bonds were ever issued and the District has no outstanding indebtedness and has never had any except for current expenses.

The District has paid the United States the sum of $500.000.00 in cash toward the cost of the project and has furnished right of way and spoil areas at an approximate cost of $225,000.00. Total expenditures by the United States since 1930 have been in excess of $20.000,000.00 including the contributions by the Flood Control District.

The total cost of the work demonstrates that it would have been impossible to create these improvements without the aid of the Federal Government. It was possible to obtain that aid for a number of reasons. Although the project was adopted as a navigation project in a Rivers and Harbors Act, the flood control feature was the important factor in obtaining adoption of the project. Since 1930 the Federal Government has adopted the policy of taking a Federal interest in flood control. Prior to that time the only interest the Federal Government had taken in flood control was in the Mississippi Valley and then only as a special case.

A second reason was because credit was sought and received for the large expenditures by State and private interests prior to 1930 in providing a cross state canal for navigation by way of the St. Lucie and Caloosahatchee canals and Lake Okeechobee. The United States allowed credit for a large part of these expenditures toward local participation in the cost of the project because they represented costs of navigation which are normally an obligation of the Federal Government. By including these costs in local contributions the percentage of total cost paid by the Federal Government was decreased to a point permitted by Federal policy.

Since the beginning of the War the navigation feature of the project has assumed increased importance because of the transportation problems of the nation. The District has attempted to bring about a much larger use of the waterway for freight transportation and some small increase has been made. It is possible that there will be a much greater increase and that the navigation feature of the project will in time be equally as important as the flood control feature. The advantages of water transportation direct from the Everglades area to all points on the eastern seaboard are great but it is not possible to give that feature any detailed consideration in this report.

It is sufficient to say that both the navigation and flood control features

of the project are of utmost importance to the area. The actual project itself has been completed and is in actual operation providing the protection against flood waters which is necessary. The United States has assumed all the cost and responsibility of maintaining this project forever. As stated before, the Okeechobee Flood Control District has a continuing obligation to the War Department to cooperate upon the project and the War Department has the continuing obligation imposed by Congress to maintain the project in perpetuity. For this reason the War Department has an active interest not only in Lake Okeechobee but in the development of the Everglades. If some one authority could be provided to assemble all of the information now available on the various features of reclamation in the Everglades and to prepare a comprehensive plan or program of reclamation, there is every reason to believe that it would be of great assistance to the War Department in its present activities and would be of even greater assistance in bringing about further interest and cooperation on the part of the United States.

CALOOSAHATCHEE RIVER AND LAKE OKEECHOBEE DRAINAGE AREAS, FLORIDA: A FEDERAL PROJECT ADOPTED IN THE RIVERS AND HARBORS ACT APPROVED JULY 3, 1930

Original construction work begun November 30, 1930, and completed July 1, 1937.

Additional construction and maintenance work later authorized by amendments to original act have continued to present time and will continue in perpetuity.

WORK DONE

1. Construction of 65 miles of levee around south shore of Lake Okeechobee from Port Mayaca to Fisheating Creek. Dimensions: Top elevation varies from 34 to 38 feet above sea level or from 20 to 24 feet above Lake level at elevation 14. Top width from 15 to 30 feet; landside slope 4 : 1. Lakeside slope varies from 5: 1 to 20 : 1.
2. Construction of 20 miles of levee around north shore of Lake Okeechobee from Kissimmee River to Nubbins Slough with same dimensions.
3. Construction of five Hurricane gates at junctions of main drainage canals with levees. Width 50 feet. Height, top of gate, 34 feet above sea level. Height of gates, 30 feet. Sector gate type used. Manual operation with provision for installation of operating machinery later if found necessary.
4. Construction of 17 culvert structures under levee to accommodate drainage waters into Lake from secondary and natural drainage canals. Culverts consist of batteries of culverts ten feet in diameter. Battery varies from 1 to 6 such pipes. Length approxiamtely 125 feet. Invert elevation approximately 6 feet above sea level.
5. Construction of two lock and spillway structures combined. Lock dimensions 50 feet in width and 300 feet in length. Usable length for navigation 250 feet; depth of water over sills minimum of 10 feet. Spillways constructed with 20 foot bays controlled by Taintor gates.

Locks are operated electrically but spillway gates are operated manually at present. Electrical operation will be installed later for spillways also.

Spillway at Ortona in Caloosahatchee River designed to handle discharge of 2,500 cu. ft. per second and at east end of St. Lucie Canal to handle 5,000 cu. ft. per second.

Locks can also be used for discharge and under operating conditions Ortona lock and spillway have handled discharge of 5,000 cubic feet per second by stream gage measurement.

St. Lucie lock and spillway will handle up to 14,000 cu. ft. per second when in full operation under extreme flood conditions.

6. Construction of one lock and Hurricane gate structure combined at Moore Haven. Lock dimensions same as others. No spillway provided but lock serves to discharge water from Lake Okeechobee into Caloosahatchee River. Upper lock gates located on center line of levee and serve as hurricane gates also.
7. Improvement of Caloosahatchee Canal and River from Moore Haven to Fort Myers by widening, straightening and deepening to provide channel with minimum bottom width of 80 feet and depth of 6 feet. Actual construction to accommodate 2.500 second feet discharge from Lake Okeechobee provided bottom width from 90 foot minimum to 125 feet and 7 foot minimum depth to 13 feet.
8. All bridges have minimum horizontal clearance of 50 feet. All bridges are swing type with unlimited vertical clearance except the F. E. C. railroad bridge at Port Mayaca which is lift type with vertical clearance of 52 feet.
9. Improvement of channel in Taylor Creek from Lake Okeechobee to Okeechobee City approximately 4½ miles. Channel width 80 foot bottom and depth of 6 feet.
10. Complete navigation charts of Stuart-Fort Myers Canal and Lake Okeechobee may be obtained from office of Okeechobee Flood Control District.
11. All construction work on project has required movement of approximately 50,000,000 cu. yds. of material with approximately 60 percent being in the levee.
12. The cost to date is approximately $20,000,000.00.
13. The right of way for project is 1.200 feet wide for levee; 400 feet wide for St. Lucie Canal and Taylor Creek, and 300 feet wide for Caloosahatchee Canal and River.

    The District has provided 825 parcels of right of way ranging in size from .01 acre to 710.79 acres and totaling 15,101.55 acres. It has also provided approximately 12.000 acres of spoil areas.
14. Right of way plats for all right of way are on file in the offices of the Clerks of the Court of the counties in which the land may be located.

Complete information on the construction and operation of the project may be obtained from the U. S. Engineers Office, Clewiston, Florida.

Figure 1.—View of St. Lucie Canal looking westward at Indiantown showing highway (foreground) and Seaboard railway bridges.

Figure 2.—View of junction of St. Lucie Canal with Lake Okeechobee at Port Mayaca showing Conners Highway bridge over the canal and old St. Lucie lock and spillway No. 1. Future U. S. Engineer plans call for removal of lock, spillway and island.

Figure 3.—View of East shore of Lake Okeechobee looking northward along levee with white service roadway on its top. The F. E. C. Railway is to the right of the levee and Conners Highway is to the right of the roalroad. The line of trees to the right of Conners Highway are growing on the sand ridge that forms a natural levee along the east shore of the Lake.

Figure 4.—View of the Town of Pahokee, looking northeastward, with Lake Okeechobee and its levee to the left.

Figure 5.—View of junction of Okeechobee Rim Canal with Caloosahatchee Canal at Moore Haven showing Moore Haven Lock and Hurricane Gate Structure at the lake end of the lock structure. Lake Okeechobee in the background with old approach channel clearly visible through the exposed lake bottom. The levee crosses the picture at the point of the hurricane gate structure.

Figure 6.—View of Caloosahatchee River just below Alva showing citrus groves and re-location of river channel, leaving small island.

CHAIRMAN WALLIS:

Thank you Mr. Herr. Our next speaker is Mr. Guy Bender, Chief Fire Warden, who will discuss the trials and tribulations of the Everglades Fire Control District. Mr. Bender.

MR. BENDER:

Mr. Chairman, Ladies and Gentlemen: The subject of fire control is a very appropriate one this afternoon inasmuch as we have had quite an oversupply of this item during the past ten days and most of you people are anxious to know what is being done regarding it.

I must say that I was very pleased to hear the motion made by Commissioner Mayo. I'd like to touch lightly on that subject for unless there is some coordination of the efforts of various agencies immediately and some definite leadership made available in the construction of dykes and other control measures, some central authority, the maximum benefits cannot possibly be expected. No doubt, if these control facilities are installed an adverse effect will be felt by some people. Individuals may have to suffer to a certain extent, because it is not going to be possible to conserve water for the entire Everglades without at least lightly affecting some of the cultivated areas. Consequently, each grower will have to install pumps and dykes to protect his own area in order not to suffer during times of an excess or deficiency of water.

I have prepared a resume of the activities and problems of the Fire Control District which, if you will pardon me, I prefer to read.

THE EVERGLADES FIRE CONTROL DISTRICT

Guy J. Bender [1]

This paper is submitted as a resume of fire control in the Everglades and covers the activities and problems of this department for the period beginning July 1, 1941, up to the present time.

The fire control problems of the Everglades can best be discussed by dividing the whole area into two sections: one known as the cultivated or farming area and the other as the wild, sawgrass area. First, let me remind you that fire is man's friend and faithful servant only when controlled but is one of the most destructive elements when it gains its liberty. Any effort to extinguish a wild, sawgrass fire that has spread over a 10 or 15 mile front, driven by a 20 or 25 mile an hour wind, makes one realize how unavailing are efforts of man and his machines to control fires of this magnitudes. The only hope for extinguishing such a fire is that the grasses on which it is feeding may be exhausted or that Divine Providence will send an abundance of rain. Fortunately, when fires occur in the sawgrass areas, driven by a strong wind, very little loss of soil occurs at this time. The reason for this is that the grass is burned over so rapidly there is little chance for the muck to ignite. Thus, only when the wind is retarded and the fire burns very slowly, does the real damage occur. Whenever the area is not too large and it is at all possible for us to cover it with caterpillar tractors and disks, we have been very successful in extinguishing the burning muck, especially if there is any moisture, whatsoever, below the surface. Without doubt, it should be mentioned too, that the problem of controlled burning of the sawgrass areas of the Glades, at such time of the year when the water table is at or just below the surface, has been undertaken by this department on numerous occasions, but our efforts have met with very little success. This is primarily due to the fact that certain conditions must be present before a complete burning can be accomplished and these conditions exist only when we have passed through a prolonged dry period and have experienced a killing frost. Unfortunately, this condition occurs only at the time when burning in the Glades is very hazardous.

In conjunction with the United States Soil Conservation Service, we have undertaken to rewater or flood various sections of the Glades during the dry period by the construction of certain temporary dams in the North New River Canal, and have proven beyond any doubt that, by the construction of the dam at 26-Mile Bend, this is possible and by maintaining water on the unfarmed area of the Glades, should fires occur and the sawgrass burn over, that there would be no danger or loss whatsoever

[1] Formerly Fire Chief and City Commissioner of Boca Raton, Mr. Bender became the first Fire Chief of the Everglades Fire Control District when it was organized in 1935. He continued in this post until July, 1938, during which period he organized an effective fire fighting unit with decidedly meager means. From 1938 to 1941 he was Manager of the Lake Shore Supply Company in Pahokee but was called back to the position of Fire Chief of the Everglades District in July, 1941, which position, with central offices and residence in Belle Glade, he occupies at the present time. Mr. Bender is a Charter Member of the Florida State Firemen's Association which was organized in 1926.

of the soil. We recommend, therefore, that some agency endeavor at the earliest possible time to construct a series of these dams in all the major canals in the Glades, and that water be impounded back of these dams during the drought periods for the purpose of overflowing the thousands of acres that are now subject to destruction. There is no question that, if these dams are installed at the proper intervals, even if they are only of a temporary nature, and are properly controlled so that, when the rainy season approaches, they can be opened up and water allowed to flow to the ocean, there can be no danger whatsoever to the farming in the cultivated areas. In our opinion, the major concern of the Glades today is the solution of the fire control problem, for, unless ours, or a similar program, for the overflow of this land is outlined and put into effect for extinguishing or controlling fires, the survey showing the depth of muck can be entirely changed within the period of a few months, for, once muck is allowed to burn for any length of time, it will destroy its elevation as well as its fertility.

While we are discussing the fire problem in the Glades it is well to mention the fact that in the last 60 days we have been faced with one of the most hazardous conditions that has existed in a number of years. In addition to having a severe drought, we have suffered the effects of a killing frost, causing all of the vegetation to become highly inflammable, so that a discarded cigarette or match could be the nucleus of a disastrous conflagration. In fact, we have just experienced one of these large fires which covered approximately 250,000 acres. There is no doubt the starting of this fire was of incendiary origin whether by a firebug or someone that just enjoyed seeing the Glades burn. However, most of the large fires we have had in the last 60 days can be attributed to carelessness and, in several instances by conditions beyond our control, brought about by certain activities resulting from the war effort.

Now I would like to touch upon fire control in the farming and cultivated areas of the Glades. While to some this problem may seem a very simple and easy one to handle, it has its complications. Whenever the vegetation in the area is killed by frost we are faced with the necessity of protecting the dikes and ditches of the drainage districts as well as the individuals' farms, dikes, ditches and road banks. Not only are these subject to destruction by fires which can be extinguished only by high-pressure pumps but, if allowed to burn, will spread to and destroy the land in addition to retarding growth or killing adjoining crops that might be covered by smoke from the burning muck.

While our department has increased its equipment from 4 units, operated July 1, 1941, to 16 units at the present time, we are still in dire need of additional pumps for, at this writing, we have on file requests from over 15 farmers for assistance and aid in extinguishing muck fires now burning on their various dikes and, in some instances, in the fields themselves. We are endeavoring to render this assistance at the earliest possible time but, owing to the lack of precipitation and since the water table is unusually low, the number of fires is way above the average. However, in normal times, we have been able to handle all requests promptly. In this same connection mention should be made of the fact that, during the last 10 days we have experienced a severe loss

to citrus groves caused by fire that originated in scrub timber adjoining these groves. While there was no provision for protection of these groves through the customary fire-break or fire-guard, in my mind it is very doubtful whether the ordinary fire-guard would have been sufficient to have prevented the destruction at the time, for the fire was fanned by a 25 mile an hour wind causing it to jump fire-breaks that had hastily been prepared of double their normal width. It is regretable that this loss was suffered, especially at this time when food is so vitally needed for the war effort. However, the other side of the ledger shows that this department has been successful in extinguishing a large fire that threatened a quarter million dollar grove in Broward County, and also prevented fire reaching seven groves in the Fort Pierce, St. Lucie County, area. It is also regretable that there was a loss of a large acreage of sugar cane which, I believe, is the first loss of this kind from a fire that was out of control. While we have a considerable acreage of muck burning at the present time, these fires are burning only a few inches below the surface and we hope to be able, through the renting of additional equipment, to extinguish most of them in the very near future. Fortunately, we have been able to extinguish all fires on drainage district and conservancy dikes.

Previous to the creation of a fire control district by the Legislature in 1935, vast areas of the Everglades were destroyed by fire. In one county alone one-third of the muck area was totally destroyed and, after the creation of the Fire Control, this department was called on to extinguish fires that had been burning for over two years, proving that, regardless of water table and rain, after a muck fire has been allowed to burn for a considerable length of time it will continue to dry out the soil and burn indefinitely or until extinguished by power pumps or by an adequate rise of the water table in the land.

The greatest danger in allowing fires to gain headway is in canal banks and along the various highways in the Everglades, especially since most of the highways consist of a rock surfacing built on muck dikes. These fires have been known to totally destroy many roads.

In compiling the records of this department for the past 18 months, prior to the first of January of this year, we find that we have been called upon to extinguish fires on approximately 262,025 acres of land which required a total of 14.794 man hours. The greater part of this land is owned by the State of Florida and the various School Districts. It is also found that the department has issued 2,015 permits for authorized fires covering 220,968 acres of land.

It has been the purpose of this department to render to the owners of land in the Everglades as efficient fire protection and control as is humanly possible. Due to the fact that the Government has now requested that every available acre of land that can possibly be cultivated and planted should be made to produce food so urgently necessary to feed the armed forces and our allies, it will require diligent effort on our part, as well as the maximum amount of funds, to prevent the destruction of this valuable land in the Everglades.

Chairman Wallis:

Thank you Mr. Bender. Our next speaker is Mr. C. P. Vinten, Coordinating Superintendent of the National Park Service. Mr. Vinten.

Figure 1.—A muck fire getting under way in the lower Glades, the top view showing the general locale, with Pennsuco at the left of center, and the lower giving better detail of the advancing head of the burn as well as the nature of the surface conditions encountered in undertaking to combat extensive fires of this type in the open sections of the Everglades.

THE NATIONAL PARK SERVICE

C. R. Vinten [1]

The National Park Service carries the responsibility, assigned by Act of Congress, for the preservation, development and operation of the great scenic, scientific and cultural areas in the United States, Alaska and territorial possessions. Strange as it may seem, our first and most important responsibility has been established by Congress as one of preservation and protection rather than one of promoting the public use of areas in the National Park system. Although it may seem strange at the outset, this policy is fundamental, because if the values of these areas are allowed to deteriorate, there will be little need for promoting public use.

I am going to speak very briefly on the proposed Everglades National Park Project, because the time is growing late, but I hope to bring the society up to date on the progress which has been made during the past year.

The work being done by both Federal and State agencies represented in this Society has contributed a great deal of knowledge which can be directly applied to our problems in the Everglades National Park. There is a very close inter-relationship between the Everglades National Park and the work and studies that have been talked about since the opening of the meeting this morning.

It is very interesting and gratifying to know that the interests represented here are now running in parallel paths; that there isn't a tendency to over-drain one area at the expense of another area, and that the tendency right now is to return the water to the lands of the Everglades from which it was originally drained. This proposal to restore natural conditions is compatible with our interests in the proposed Everglades National Park.

More progress has been made in the past two years toward final establishment of the park than was made in the preceding eight or ten years. Lands in the area have been released from the bonded indebtedness of the Everglades Drainage District, legislation has been enacted to facilitate the acquisition of lands by the State and the conveyance of a park area to the Federal Government; the problem of oil and gas exploration has been brought to a reasonable conclusion, and the program for the area has reached a point where the important phases of land acquisition are now in progress.

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The Act of Congress of 1934 provided that the park would be established as soon as an area satisfactory to the Secretary of the Interior is conveyed by the State to the Federal Government. On the basis of negotiations during the past two years, I feel quite confident that under the capable leadership of Governor Holland, the State of Florida will be in a position to convey these lands within the next year and a half or two years.

The motion made by Mr. Mayo is of particular interest to me because in protecting this area, we are interested not only in protecting what is under the ground and what is on the surface, but also there is a third step to be introduced, and that is protecting the things that fly through the air—that is the third stratum in the geological chart that you could add, and incidentally that upper stratum is also very dependent upon what happens on the surface of the ground and under the ground. It is well to recommend that a coordinated plan be worked out, because there is so much more than farming represented here. There is the tremendous tourist trade to protect, rapidly growing populations and many other things all dependent on water supplies. You have a problem of commerce, a problem of traffic, all of which are inter-related. In other words, if you are going to dig a canal to drain something or a canal to inundate an area, and if that canal can be dug and its spoil bank used to build a highway, and that highway used in a well-designed system of arterial traffic, you have gained something. There is no doubt in my mind that with the establishment of the Everglades National Park, very definite flows of traffic will be developed that will indicate a certain need for arterial highways. So, in studying this great region of southern Florida, say starting at Orlando and extending on down to Florida Bay, there is no one interest that you can say is predominant. Here are the interests that lie in these three strata; the interests under the ground, the interests on the surface and the interest that flies through the air. If we protect all of them, the state and nation will benefit greatly. If we work out a plan at the start for the entire southern part of the state, we might realize at the start that the plan may not be followed to completion, but if only half of it were followed, we'd have twice as much as we have now. Looking back over the intimate connections I have had with this part of the state over the past twenty years, I can at least say that in one generation we won't be draining the water from the Everglades and in the next generation, putting it back on again.

I hope that when this program is drawn up that it will consider the many varied interests of the Everglades and the entire southern part of the state; that is of agriculture, tourist travel, transportation, water resources, wild life, plant life, scenery, so that no one phase will be overlooked, and above all, that when that program is outlined, that the facilities be provided for carrying it to completion, so that the great amount of work that has been done so far in surveys and investigation, may not be lost.

Many public and private agencies in Florida have a vital interest in the proposed Everglades National Park. The Everglades National Park Association has promoted the area, has promoted its establishment since the original conception of the idea, and has kept the project alive

during trying periods when it might have become dormant or passed out of existence. The Everglades National Park Commission, a State agency created by legislative act, has completed abstracts on all lands within the park boundaries, has done considerable work on ownership maps, and has handled many complicated problems of administering the business phases of the area from the standpoint of the State of Florida. Governor Holland and the members of his cabinet have solved many important problems which, during past years, have been considered insurmountable obstacles. These obstacles have been, in many cases, entirely eliminated, or simplified to the point where they no longer obstruct progress. The United States and Florida Geological Surveys, National and State Audubon Societies, local and State Chambers of Commerce, and many other interests in Florida are active in promoting and actually helping with the protection of the area, as well as contributing to a solution of its problems. The project has now reached the stage where acquisition of park lands is in progress; a stage which has been reached for the first time in the history of the area. It is quite important that we consider the Everglades National Park as a project for post-war planning and development.

I appreciate this chance to appear before such a representative and distinguished audience. I hope that when a plan for South Florida is worked out, that I will have the opportunity to follow it through, because I know that this extreme southern part of the Everglades is so dependent on what happens in the areas to the north that our protective work in the Everglades National Park will be greatly simplified as the problems above it are solved on a basis of reasonable planning.

Time will not permit a discussion of the methods of proceeding with such a plan. However, during the conferences of this Society, I have tried to visualize a program which would be favorable to the proposed Everglades National Park, as well as to all other interests in this great region.

In order to establish definite objectives for the guidance of a program of surveys, investigations and plans for the Everglades region, there is set forth below a tentative outline for the guidance of such a program. It is obvious that this outline is merely a preliminary gesture which may lead in the direction we should all like to travel. It is hoped that this preliminary idea may result in study by others, so that revisions and corrections may be made, and a written program placed on record that will be acceptable to everyone concerned.

TENTATIVE PROPOSAL FOR A REGIONAL PLAN OF THE SOUTH FLORIDA DRAINAGE BASIN

A. The establishment of a central authority with power to compile surveys, make studies, approve plans, and execute plans; and the designation of a technical or advisory council to serve as a consulting body only.

B. The extension of geological, meteorological, topographical, hydrological, soil and biological surveys, to cover the entire basin south to Florida Bay, including a record of present land uses. Surveys and studies of existing conditions might be recorded on separate sheets or sets of sheets as follows:

1. Topographical — contour, general ground cover, location of drainage, traffic and communication arteries, land ownerships and improvements.
2. Hydrological — surface and subsurface waters.

3. Geological — surface and subsurface formations.
4. Meteorological — rainfall, temperature, etc.
5. Soils — both agricultural and non-agricultural areas.
6. Biological — both native flora and fauna.
7. Population records and trends, traffic flows, housing, labor, etc.
8. Standardization of map scales and sizes, symbols, and presentation, to facilitate overlapping studies during the planning period.

C. The establishment of a planning unit or units to be coordinated under the central authority for the actual preparation of plans for:
1. Water control — drainage, impounding, distribution, irrigation, storm protection, and the restoration of natural conditions where necessary, for the entire basin, south to Florida Bay.
2. Zoning of land uses — farming, grazing, community planning, forestry, soil conservation, fire control, oil and minerals, wildlife conservation (both flora and fauna), health and sanitation, water pollution, game sanctuaries and hunting preserves, commercial and sport fishing, parks and recreation, preservation of scenic conditions; and Indian Reservations.
3. Transportation and communications — highways, waterways, railroads, airports, power and telephone, etc.
4. Educational and cultural developments — schools, libraries, local parks and playgrounds, etc.
5. The drafting of laws or regulations needed to provide authority for the execution of the plan.
6. The determination of a period of time to be covered by the plan. That is to say, should we plan 1 year, 10 years, or 50 years in the future? This is an important consideration which may be determined by a study of population and use trends of past years. As a guess, I should say we could proceed safely with a 20 year plan.

D. The establishment or designation of an administrative agency with the authority and resources to carry out the plan. Some agency patterned after the Tennessee Valley Authority would be the answer, in order that all phases of the above program and plan might be studied and actually put into operation.

CHAIRMAN WALLIS:

Thank you Mr. Vinten. Mr. Bestor will now discuss the "Reclamation Problems of Sub-Drainage Districts Adjacent to Lake Okeechobee". Mr. Bestor.

RECLAMATION PROBLEMS OF SUB-DRAINAGE DISTRICTS ADJACENT TO LAKE OKEECHOBEE

H. A. Bestor[1]

The reclamation problems of Sub-Drainage Districts adjacent to Lake Okeechobee in Florida, are similar to all other unit area developments in the Everglades, except for their proximity to this Lake. Because of uncontrolled waters, all so-called "improved lands" in the Everglades face seriously critical situations as to land use and conservation of organic soils. These difficulties are closely interwoven with problems in and outside their boundaries. Therefore, in reclaiming unit tracts, consideration must be given to the entire situation in the Everglades.

An understanding of this interdependence of water management explains most of the difficulty that the Engineer has in designing unit plans, and many of the problems of Sub-District organizations in maintaining and operating their reclamation facilities. Engineers are handicapped and landowners are penalized because the Everglades Project has no established over-all policy and plan to control its reclamation. There is no directive authority to pass on the engineering sufficiency of unit area plans nor to regulate procedures for maintenance and operations for the permanent benefit of property.

In the previous talks today, you have heard a review of factual information recently gathered by the various Federal agencies and the opinions of scientists who have dealt with soil and water situations in the Everglades for many years. These talks have been impressive and certainly leave little doubt in one's mind that the Everglades really has problems about which, as yet, we have done very little.

They remind me of a story I once heard. "A well known Southern family had an old darky who had faithfully served them for many years, so they decided to reward him. They gave him a small undeveloped tract of land in their plantation so he could have a place of his own for his remaining years. The old darky was quite pleased and industriously went about making a home for himself. He built a cabin, cleared, tilled and planted the land and gradually accumulated some stock—a mule, a cow, some hogs and chickens and, in time, gained quite a respectable reputation for his place. The local Parson often called and inspected the things on Joe's place, always remarking, 'Joe, you and God sure has done wonders around here. You keep praying and thanking God for all He has done for you.' When the Parson was transferred to a city congregation, he called to say goodbye and again emphasized all that God had done, and he was leaving, Joe said, 'Yes sir, Parson, I'se mighty proud of all God has done for me but, Parson, I just wish you could hab seen dis here place when God done run it hisself'."

We may not be letting God run the Everglades alone, but we certainly have not been as successful as Old Joe apparently was in helping to do

[1] Drainage Engineer, U. S. Sugar Corporation, Clewiston, and Consultant various of Sub-Drainage Districts Adjacent to Lake Okeechobee". Mr. Bestor. ceedings, Vol. IV-A, p. 90.)

something with it. Florida has been "wishfully thinking" about reclaiming the Everglades for nearly a century; yet we are forcibly reminded today that we are letting our resources insiduously waste away. Of course, much has been accomplished as is evidenced by the fact that we have traversed the Glades by railroad or over substantial highways in automobiles to this meeting today in the heart of the Everglades. This is a far cry from trips most of us can recall little more than a decade ago, when we had to reach the Lake region by boat.

All advantages in the Everglades today, land use, general activities, habitation of the territory and, in fact, all investments of capital and effort in South Florida are a direct result of having relieved the Everglades of its original bondage by water. It is easy to visualize what these developments have meant to the State of Florida and to our Nation. The returns in general taxes alone have paid many times over for all conceivable costs of reclamation. As a matter of fact, when all such economic factors are taken into account, reclamation costs have been ridiculously low and it makes one wonder if the people of Florida fully appreciate the tremendous asset they have in the Everglades.

The doubts and difficulties which cooled public opinion and hampered early reclamation efforts most certainly have been dissipated by present established economic values and it is to be hoped that public interest is now awakened to a fuller appreciation of reclamation processes, so that we can improve situations, stabilize the progress made and conserve the resources of this great project for the future.

Present progress is the direct result of activities during the past twenty years. It is a pioneer project in its infancy and subject to mistakes common to all first endeavors. At least, we know that we are facing seriously critical situations of soil and water control because we have virtually "overdrained" the Everglades and have created many confusions by indiscriminate developments of land; and that the present handling of reclamation processes is not providing complete or desirable results. The Everglades cannot afford to continue these mistakes. It is now high time that we take a realistic inventory of situations and go about putting our reclamation business in order. With this viewpoint, let's review the status of reclamation to date:

RECLAMATION OF THE EVERGLADES DRAINAGE DISTRICT

Examining Engineers have commonly agreed that the reclamation of the Everglades involves two major factors: first, that the flood waters of the northern high land watershed should be controlled through its collection and regulation in Lake Okeechobee, as a storage reservoir, with outlet channels to dispose of water to the ocean, so as to prevent water from overflowing into the lower basin area to the south; and secondly, that lands could then be handled by ditching by considering only the precipitation (rainfall) on the land itself.

This principle is set out in the 1913 report of the Isham Randolph Engineering Commission which activated the Everglades Drainage District in financing and carrying out the work represented in the present arterial canals and other facilities now controlling the reclamation of the Ever-

glades. Although this is commonly referred to as the Randolph Plan of Everglades reclamation, it actually is only an Engineer's Report.

The facilities of this so-called "Plan of Everglades Drainage District" consists of the West Palm Beach, Hillsboro, North New River and Miami arterial canals and some few lesser channels and of the Lake Okeechobee control works, including the Federal rehabilitation of Lake levees and structures with its improvements of the Caloosahatchee Canal extending to the Gulf of Mexico and the St. Lucie Canal to the Atlantic Ocean.

Drainage of the Everglades has been accomplished with this skeleton scheme of outlets. Influence of this drainage, however, has only been notable since the year 1931 when the U. S. Engineers assumed responsibility for the rehabilitation of the Lake control in the interest of navigation and flood control. The Federal government has spent more than twenty million dollars on the construction of Lake levees and structures and on improvement of channels in the Caloosahatchee River and St. Lucie Canal. Federal administration has increased the stability of levees and has planned for control of lake stages between fourteen and seventeen feet above mean sea level and, since 1931, has rather consistently controlled lake stages at about sixteen feet above sea level.

It is easy to understand the influence this had on drainage when you consider that the original "overflow" elevation was about twenty feet above sea level and that under Everglades Drainage District administration (prior to 1931) the lake stage was generally near eighteen feet above sea level, except during particularly dry years or flood periods like those provided by the storms of 1926 and 1928.

Prior to 1931, arterial canals were usually overburdened by high lake stages and their contiguous land waters. Since 1931, these arterial canals have had more opportunity to remove water from the lands adjacent to them because of consistently maintained low lake stages combined with distribution of rains and absence of severe storms.

This influence on drainage is clearly depicted in the "valley effects" shown by the profile contours and cross sections so pointedly discussed by Mr. Albert Stephens of the U. S. Soil Conservation Service this morning.

Early agricultural efforts unsuccessfully attempted to drain lands by gravity toward arterial canals, but satisfactory water control requires pumping. Commonly now, through encouragement of Everglades Drainage District, various Sub-Drainage Districts, unit areas and owners of individual tracts have diked and ditched land and installed pumping plants to obtain access to and disposal of water in Lake Okeechobee or the arterial canals of the Everglades District.

This pictures the principles and describes the existing general scheme of reclamation. It seems practical, yet it emphasizes drainage rather than water control, and lacks completeness of detail.

For instance, control of flood waters reaching Lake Okeechobee does not entirely eliminate all the flood flows affecting lands in the Everglades. Other high land areas directly contribute run-off which accumulates with the precipitation of rains on the low lands, such as the area of the Okaloacoochee Slough on the southwest and the area of the Allapattah Flats on the northeast of Lake Okeechobee. Also, back country drainage naturally flows toward the basin area of the lake. These flood effects

combine in creating situations which require consideration to protect developed areas from the encroachment of waters outside of their boundaries.

Further than that, regulation of Lake Okeechobee waters involve factors of quantities and time movements which may be greatly affected by thoughtless drainage developments in Kissimmee River Valley. In view of the situation discussed today, it seems evident that any scheme of reclamation in the Everglades must consider the conservation of all its natural resources. It is even possible that we may have to revise our entire viewpoint on "Lake Regulation" and that water stored in Lake Okeechobee may have to be conserved more particularly in the future for land use.

Altogether, it seems to me that reclamation problems of the Everglades rest fundamentally in the question of *Hydrology*, using this term as meaning "water control" in dealing with distribution and disposal of rainfall over the entire land area. In this sense, hydrology is the borderline science of interest to, and the common meeting ground for all, Agronomists, Engineers, Meteorologists, Geologists, Soil Technicians and any others concerned with any phase of problems affecting the development or conservation of the Everglades.

Reclamation of unit areas must consider the amount and movement of waters over all land surfaces in their vicinity, in relation to surrounding topography and rainfall. Flood water is no respecter of quality of land —it rains equally as hard and presents equally difficult problems of flood control on good, bad and indifferent land.

RECLAMATION BY SUB-DRAINAGE DISTRICTS

The seven principal Sub-Drainage Districts adjacent to Lake Okeechobee, extending from Moore Haven to Canal Point, are political subdivisions of the State of Florida, and have been created under General or Special Acts of Legislature as integral units of the Everglades Drainage District. They embrace a reclaimed area of some 95,400 acres, have 19 pumping plants using 36 pumping units, employing engines totalling 5,000 horse power and having a combined capacity for handling approximately 1,780,000 gallons of water per minute. The detailed distribution of these facilities is more particularly described in Table 1.

In addition to these legally organized Sub-Districts, about 100,000 acres of land in the Lake region have been individually diked and ditched. These reclaimed areas have an estimated combined pumping capacity of approximately two million gallons of water per minute.

This indiscriminate development alters the movement of back country water and burdens the various arterial canals into which they pump. This causes Unit Areas and Sub-Districts periodically to face difficulties with flood water influences beyond their respective control. These situations are created because the existing facilities of Everglades Drainage District are not capable of disposing of water in time to prevent hazardous conditions. It is easy to recall the results of previous situations when flood waters have overflowed the banks of the various arterial canals and highways, creating much concern to communities like Canal Point,

TABLE 1

Distribution of Facilities Among Sub-Drainage Districts Adjacent to Lake Okeechobee.

Sub-Drainage District	Acres Drained	Pumps No.	Pumps Kind	Total E.H.P.	Capacity G.P.M.	Outlet
1. Disston Island Drainage District						
(a) Pump Unit No. 1	9,974	2	W.S.	360	130,000	Lake Okeechobee
(b) Pump Unit No. 2	9,974	2	W.S.	360	130,000	Lake Okeechobee
2. Sugarland Drainage District	10,293	2	W.S.	360	140,000	Lake Okeechobee
		1	W.S.	120	40,000	Lake Okeechobee
3. Clewiston Townsite	2,788	2	W.	160	52,000	Industrial Canal
	540	1	C.P.	30	10,000	Industrial Canal
		1	C.P.	50	16,000	Industrial Canal
4. South Florida Conservancy District						
(a) Pump Unit No. 1	6,878	2	W.S.	360	112,000	N. N. R. Canal
(b) Pump Unit No. 3	5,780	2	W.S.	360	112,000	Lake Okeechobee
		1	C.P.	45	16,000	N. N. R. Canal
(c) Pump Unit No. 5	10,701	2	W.S.	360	112,000	Lake Okeechobee
		1	W.S.	180	60,000	Industrial Canal
(d) Pump Unit No. 2	1,359	1	W.S.	180	60,000	Hillsboro Canal
(e) Pump Unit No. 6	7,665	3	W.S.	540	168,000	Hillsboro Canal
5. South Shore Drainage District	4,300	2	C.P.	160	72,000	Lake Okeechobee
6. Pahokee Drainage District—East Unit						
(a) Pump Plant No. 1	5,798	2	W.S.	360	120,000	W. P. B. Canal
(b) Pump Plant No. 2	9,478	3	W.S.	540	180,000	W. P. B. Canal
Pahokee Drainage District—West Unit	6,470	1	C.P.	120	60,000	E. D. D. Canal
7. Pelican Lake Sub-Drainage District						
(a) Pump Unit No. 1	3,380	2	W.S.	160	60,000	W. P. B. Canal
(b) Pump Unit No. 2	2,895	2	W.S.	160	60,000	W. P. B. Canal
(c) Pump Unit No. 3	1,420	1	W.S.	80	30,000	W. P. B. Canal
TOTAL	95,960	36		5,045	1,740,000	

Pahokee, Belle Glade. Chosen. South Bay and Lake Harbor and threatening all reclamation operations. These situations are alarming when you visualize the devastation which is possible now that the area is so highly developed and populated.

To design a plan of reclamation for Sub-Drainage Districts, an engineer must have an understanding of the climatic and soil characteristics of the territory he has to deal with. Water must be regulated in a scheme of ditches so as to maintain soil moisture with consideration for the agricultural use of the land. This does not mean that a scheme of reclamation must establish so-called "water tables" in the land for various types of crops. It means that it must set relations of water surface gradients and ground surface elevations which will provide for storage of water in the soil, dependent on precipitation. percolation through the soil. and the average expectance of surface run-off. Such factors have been established in the Lake region by extensive studies of soil characteristics and by examination of records of intensity and duration of rainfall. Studies of run-off were originally commenced in 1926 by using weather observation records of established stations scattered throughout the area —Fort Myers, Arcadia. Jupiter, Moore Haven, Ritta, etc. Interpolation of these records were plotted to determine the expectance of rainfall at intermediate points. We now have numerous recording stations in all the Sub-Districts around the lake which substantiate these original interpolations. Combined with the study of rainfall, we have made observations of soil water movements from ground surface profiles and wells to determine the economic features for practical rates of water velocity, size of water channels, length of water haul, or, in brief, all factors involved in the effective movement of water. Designing a scheme of water control for the flat organic soils of the Everglades requires even more detailed attention than does designing a storm water sewer system for an urban area. Each ditch must receive water from a specific area of land and the accumulation of water must be handled in a main outlet with the same care as gutters and catch basins of a street and conduit pipes of proper size dispose of a city's storm water. Ditching is not merely a question of making a channel "plenty big". As a matter of fact, a channel which is too large handicaps drainage in the same sense as any depression or pot hole in the farm. This is understood by reflecting that if you double the cross sectional water area of a channel the rate of movement (velocity) will be half as fast to deliver a specific volume of water.

In general, a plan of reclamation for a Sub-District in the Everglades is dependent on two correlated sets of water control facilities, first, a system of embankments (levees) around their unprotected boundaries so as to effectively shut off extraneous waters, and, secondly, a system of collecting canals and laterals regulated by a pumping plant so located as to have an outlet to dispose of excess drainage water and access to supply water into the lands through a facility of Everglades Drainage District.

Such ditching sytems have generally been designed for a run-off compatible with the local precipitation on the land so as to afford adequate outlet for all land contiguous to each integral ditch and so divid-

ing areas of land that no point of drainage will be more than one quarter of a mile from an outlet. The level nature of terrain makes it practical to dig ditches in conformity with legal land lines. This lends itself to convenient division of land and farm units and gives each tract of land a ditch frontage. Main canals are generally spaced at two mile intervals and have a maximum water haul of six to eight miles, with perpendicular laterals spaced one half mile apart with a length of one mile.

Sub-Drainage reclamation schemes do not provide the full requirements of detailed water control. They merely provide the system of canals and laterals which supply and dispose of the land waters. The detailed soil moisture control is left to the discretion of each respective landowner. The Engineer should submit a "Schedule of hydraulics" as an integral part of his plan of reclamation to specify the purpose of design and to establish the relation of water surface and ground elevation at each respective junction in the ditch system so as to definitely fix the important obligation of maintaining and operating the Sub-District's reclamation facilities in the interest of the landowners.

This illustrates a typical Sub-Drainage District's plan of reclamation. It is essential that both the Sub-District management and landowners respect the obligations set up by the Engineer's design of reclamation. There must be uniform control of water to guarantee each landowner equal benefit from manipulation of water.

INTIMATE CONTROL OF WATER FOR LAND USE

The detailed water control for the intimate agricultural use of the land involves proper preparation of the land and tilling the soil, together with intelligent spacing and dimensions of surface and sub-soil drains intercepted by field ditches connecting with the facilities of the Sub-District. To obtain proper soil moisture for agricultural use of the Everglades muck lands and to conserve its delicate organic soils, the farmer must manipulate water in coordination with the plans and regulations of the Sub-District. Very often, this requires auxiliary pumping to meet the specific needs of the farmer. Water control by the farmer is dependent on the plans and management of the Sub-District in the same sense as the Sub-District is dependent on the plans of Everglades Drainage District.

PROBLEMS OF DEVELOPED UNIT AREAS

Sub-Districts are partly dependent on levees along Lake Okeechobee and arterial canals controlled by Everglades Drainage District. Levees of Sub-Districts were generally built four feet above natural ground surfaces in anticipation of normal floods. However, these levees and the lands within Sub-Districts have now subsided more than two feet since the original planning of reclamation facilities. Also, indiscriminate diking of other lands affecting the movement of back country waters, combined with promiscuous pumping by random tracts of land aggravates the normal disposal of water. All together, these situations create emergencies which periodically jeopardize the security of the land against

floods and interfere with normal reclamation processes and use of the land in Sub-Districts.

Many other confusions of water control have been created because of district organizations and farmers having been negligent of plans to maintain and operate their reclamation facilities.

Lands are now commonly used only during the dry season for winter vegetable farming and little interest is taken in what happens during this season. This present haphazard consideration of water control is responsible for much of the loss by subsidence. Farmers are presently exploiting the soils for their immediate advantages and must eventually pay for such operations. Present neglect will become increasingly apparent with the continued use of the land. All present land use is challenged by lack of appreciation that conservation of its organic soils is vitally dependent on water control management.

From the information presented today and from personal dealings with the development of Sub-Drainage Districts and reclamation situations in the Everglades, it is my opinion that water cannot be independently handled and that no areas of land can be developed or conserved without the general considerations surrounding them. In other words, potential land use values are dependent on control of Everglades waters as an entire project.

The satisfactory development of the Everglades must take into consideration that water effects originate from physical limitations of land and cannot be confined to arbitrary boundaries; that emphasis must be placed on benefits of conserving rather than on disposing of water as a common enemy; that water control planning is necessary for the preservation of wildlife, the development of a National Park, the conservation of idle lands to control subsidence and prevent burning of muck lands, the utilization of lands for agricultural purposes and for the preservation of municipal water supplies. Taxation of lands must be fixed in direct relation to hydrological effects and future land use as some lands are not suitable for agricultural use and will bring no tangible revenue but, even so, have a definite public value.

Arbitrary selection of lands cannot be expected to conform to physical limitations. Present occupation, dispersed ownerships and indiscriminate sale of lands is detrimental to economic reclamation.

We now have the easement of current tax burdens of Everglades Drainage District, the construction of highways furnishing easy transportation and the war situation creating a desire to buy and develop more lands. This emphasizes the need of planning before our existing problems become further complicated and demands a complete physical and economic diagnosis. This can best be accomplished through the agency of a competent Engineering Commission, independently employed, under State authority. Engineers of national reputation and unquestioned ability could analyze the situation and make definite recommendations for the solution of problems. With the existing information (of all kinds) which can be made available to them, Engineers could prepare a comprehensive report, similar in scope to the Isham Randolph Report, which would recommend policies, suggest the probabilities for an Over-All Plan and the requirements of any desirable legislative action.

I would like to renew the recommendation that was presented a year ago at the meeting of the Society in West Palm Beach: [2]

"It is recommended that the Soil Science Society of Florida present the importance of protecting the Everglades from the existing wasteful abuses of its resources to the Honorable Spessard L. Holland, Governor of Florida, to the Trustees of the Internal Improvement Fund, and to the Board of Commissioners of the Everglades Drainage District, requesting that they give consideration to the employment of an outstanding engineer and commission to investigate the present problems of the Everglades by analyzing the present status of land ownership, all organization and engineering facts, conditions in contributory water sheds, existing reclamation facilities, the relations of Lake Okeechobee control and of the Everglades Drainage District and its sub-drainage districts and other occupation of land, all with a view of determining the problems of the Everglades drianage areas so as to recommend the immediate steps to be taken to curb the present waste of land, to protect present ill-advised developments, and to prepare a definite Everglades plan for the reclamation and conservation of the soil and water resources of this great area."

Chairman Wallis:

Thank you Mr. Bestor. Now Mr. Gunn, I not only admit, but brag that we had a dress rehearsal of the speeches here today, with the exception of Mr. Mayo's, Mr. Wilcox's and Mr. Carleton's. However, before calling on the next speaker—we sort of crossed him up in the rehearsal we had - I think you will all agree that information resulting from the discussions of these experienced people results in a unanimous call for a definite policy or plan. Now I would like the next speaker to give us the problem as presented from the standpoint of the Everglades Drainage District in the administration of the plan; and I would like him, to the extent possible, to give us encouragement that, if selected by proper authority to be that contral agency, that they will be willing to accept that responsibility. Before calling on him, I would like to say that Mr. Lingle was prevented from attending by an unexpected meeting of his Board. The next speaker will be your local member of the Board of Commissioners and General Manager of the Everglades Drainage District, Mr. J. E. Beardsley of Ritta and Clewiston. Mr. Beardsley.

[2] The Principal Elements of a Long Time Soil and Water Conservation Plan for the Everglades. H. A. Bestor, The Soil Science Society of Florida, Proc. Vol. IV-A, pp. 90-99, 1942.

EVERGLADES DRAINAGE DISTRICT

J. E. Beardsley [1]

It is about closing out time, and I expect you are all as weary as I am, and I don't expect I will take any burden off your minds. I am going to close at the end of fifteen minutes, notwithstanding Mr. Wallis has placed on me a considerable burden, if he expects me to say what the coordination of the plan and the information developed here today and at the meeting last year means to the present overall agency. The geologists, ecologists and soil survey people are all talking about matters within the boundaries of the Everglades Drainage District. You have heard a lot about its problems, and I think Dr. Allison has probably stated to you on one side conscientiously and concretely the problems and existing phases.

There is, however, another side, and that is the fiscal, and it is one that has been repeatedly overlooked in all the discussions with reference to Everglades Drainage District affairs for the years in which I have been connected with the District. I can recall attending meetings in the Belle Glade City Hall here on more than one occasion and saying for the District, to the office of the U. S. Engineers, "We are not interested in having you remove hyacinths from the canals, if after that job is done, you expect us to maintain them free of hyacinths, because we are broke!" Now I say to you as people interested in this District, and I recognize faces of a number of taxpayers here today, that we are not much better than broke today, insofar as money for rehabilitation and maintenance is concerned.

Now, understand, no one could be more appreciative of the physical problems brought out by Dr. Allison and other speakers today than I am. I have lived with them for 29 years, and as an official of the District, I am in a position to say for the members of the Board, three of whom have been here today, that we understand; we take it as our job to see that this asset of the State of Florida and this property of the stockholders of this Corporation, the people who foot the bills in taxes, is not dissipated, but I won't have you leave here under the impression that all that is necessary is to prepare a program of what needs doing. I would not be doing justice to my present job if you went away from here with that idea, because it is going to take dough, and I mean real dough—long-green. You can't do the jobs that have been suggested here today without laying it on the line! That is good common farmer straight talk, but that is going to be necessary. Now you might say I am a pessimist—I am not. I am an optimist! If I wern't, I wouldn't still be here after 29 years in the Glades—that is patent. There are more of us (pointing) one over there, another over here—we are optimists or we wouldn't be here.

I think we can begin to accomplish some of the things that we all have in mind. For instance within what is commonly called the Hillsboro

[1] Member, Board of Commissioners, and General Manager, Everglades Drainage District, Clewiston. (See also Proceedings, Vol. IV-A, p. 104, 1942.)

Lake area—we call it Kay's playground because he likes to have people hunt and fish there. I think it would be a wonderful attraction to have this area in the District stay under water and certainly that is economically sound as far as the soil is concerned—that will preserve it. It is not agricultural soil, we all agree. Now we people agree, but the average taxpayer who is going to have to foot the bill, is still going to have to be sold a bill of goods. You have still to sell them on what is necessary to be done.

There are any number of people in this District today who are not aware of the things we all know. Why? Because we are vitally concerned with the entire area, either because it is our job, or because we live in it and have to live in it, like some of us, but the average man in this District today is still as provincial as he was when he came here. He is concerned with what happens to "my farm" and not whether we are going to take some of his tax money and put an area up there (pointing) north of the Hillsboro Canal and say this is poor soil—you've got to sell him. That is one aspect that I want to bring out about the physical side, and I think I made my point. I don't think I need to solicit any sympathy in behalf of the Board. Some of you recall a man you've heard of by the name of Sanderson—this is the best way to get over my point. Now I am sold after discussion with people who know more about the Everglades features than I do, that water should be impounded on presently non-agricultural soil, that Road 26-A should constitute a barrier, but here comes a man to the Board and says, "I want the water off my land—I have just been instrumental in having other people purchase the State's title (by the State, you understand, I mean the title to the Trustees of the Internal Improvement Fund) we propose to go farming—give us some drainage." As a matter of fact, we didn't give it to him. I am not certain, because I am not an attorney, but I believe that there exists today laws which state all we need, to do the things that have been suggested here, insofar as legislation is concerned. I don't say that positively—I might have to hedge—but I think they exist—at least we made this one case good.

Let's cite some of the fiscal problems, and I am not going to say we will find a solution in the next thirty days and hereby get any additional legislation we might need. I think we need a plan, but I say to you taxpayers, agency men, whoever you be, who are interested, that we are ready to try to operate a plan which is developed by you people, who are being paid for the job of getting this information; on it and on it only, can we base what we ought to do, as the geological survey knows. We are cooperating with them, and I hope we will be able to provide them with more funds for what they are doing. I come right back again to the fiscal side. With the aid of the Soil Conservation Service, Geological Survey and three or four other agencies, we could collect a lot more needed information, but not with the funds they have on hand, and we are not in a position to supply them with any additional. That kind of bridges the gap from the fiscal to the physical.

I want to warn you that when I give you the figures I am about to set up, I repeat when I say debt service I mean debt service, not money we can use on these jobs, but I think the report is due you, and I conceive

it to be my duty to give you one at this time. You might be interested to know that this (pointing) is realistic zoning and that is the reason I hauled it out at this time, and I can't help but note the fairly equitable distribution of taxes with reference to the quality of land as exhibited on the adjacent map. That being so, we want to know what was the answer.

In 1941, tax collections in the District on the basis of realistic zoning—realistic taxes for a levy of $632,000—were $394,000 in the fiscal year ending October 31, 1942. There has since that time been nearly $20,000 additional redemptions in 1941 taxes. How are we getting along in 42? At the end of February this year, we had collected $157,000 in current taxes since the first of November, and last year $138,000 up to the same time. I am attempting to indicate a still improving condition in the district tax collection.

Where do we stand today? We owe RFC $5.300,000. The Board is seeking some opinions from taxpayers as to how it shall handle a treasury surplus which has accumulated. I speak of a surplus—this is an accumulation of taxes set aside for the debt service funds of the District which today amount to approximately $480,000 with all interest and commitments paid. That is $230,000 over the reserve required by RFC—that amount will probably be $300,000 by April, and it is possible by the first of July, notwithstanding payment of $106,000 interest, a still existing surplus of $300,000. One of the problems is, shall the Commissioners hang onto that surplus as a hedge against future bad times, as is being suggested, or should it pay off part of its mortgage, reducing the loan to $5,000,000; it is nice business, cuts your interest rate. I repeat, you are all stockholders in this District. Having paid $300,000 or with the possibility of doing so, you should be interested to know that only two weeks ago we discussed with the Drainage Division of Reconstruction Finance Corporation, the possibility of a rehabilitation loan to enable the District to do some of the immediately necessary jobs—one of which I think is some additional work in the Hillsboro Canal—that usually gets a smile. The other is the establishment of the controls mentioned by Mr. Bender, and Mr. Davis. It is true we have wasted a lot of water this fall and this winter—a lot of water went to waste out of this District. That condition has to be cured—we might have another dry year next year. It isn't likely, but it is conceivable and something has to be done about it.

We don't know whether we are warranted in transferring the surplus to RFC—that is what we want to know from taxpayers in the District. What is the answer? What do you want us to do?

On the maintenance side, when I said we didn't have any money, I meant just that. Maintenance tax in the District comes from a half mill ad valorem throughout the District, and the levy this year will be sufficient to provide approximately $61,000, of which some $28,000 is committed to administration. I won't have you believe that all went out in salaries—which is the general impression. There are a tremendous number of small items, treasurer's bonds and things of that sort. That leaves, with some other prospective resources, possibly $40,000 that might be available for maintenance work, and you engineers know better

than I do that $40.000 would be a drop in the bucket on some of these jobs we know equally well are necessary to carry out a long term program.

Now I think we ought to have in mind some idea where we are going—not for the next year, but for the next ten. It will need to be changed as circumstances vary.

I am heartily in favor of the motion or the resolution and amendment here today. I don't want to go to Tallahassee—I think the Trustees of the Internal Improvement Fund are sufficiently interested to come down here and talk with us and discuss the program, because so long as they continue to permit sales of reverted lands, then your District is going to have a problem on its hands of setting up conservation areas. How can we say we are going to do certain things, if speculators or investors can go into any county seat and say "I want to purchase these reverted lands." and the Clerk is compelled to put them up. Attorney General Watson says there is nothing he can do about it. I am sorry Commissioner Mayo has gone, because I wanted particularly to speak to him and discuss that problem with him. I talked it over with Governor Holland and with the Attorney General. I am not unduly concerned with the future of the Everglades. In the course of a year or two, probably we will stand in much the same position as the Trustees of the Internal Improvement Fund have stood in the past—we will be large landowners in the District, and then we will be able to exercise the type of control over these areas we deem necessary.

I think I've got off my chest, all the things I wanted to.

CHAIRMAN WALLIS:

Thank you Mr. Beardsley. In concluding this phase of the program I find great pleasure in introducing to you one of the real farmers in the Everglades whom I would like to ask for a few remarks on conditions as he finds them just as frankly as he may care to let us have them. Mr. Howard Haney.

MR. HANEY:

Mr. Chairman: It is very discouraging to hear that we have no money. We are not thoroughly familiar with the financial condition of the Everglades Drainage District, but we are familiar with the work it does. Why in the fall, when it begins to rain, you know it is just a phenomenon the huge volumes of water that the Hillsborough Canal won't carry, and then when we are in the midst of a drought, it is definitely appalling how rapidly it will carry the water off.

Ninety per cent of my pumping is pumping in and not out. Therefore, 90 per cent of my use of water is irrigation and not drainage, because there is only about a month in the year that I need any drainage. I have been irrigating ever since last December, and I shall have to continue to irrigate until I get through farming in the spring unless we get some rain. In the fall of the year, however, what we farmers have to be worried about is whether Lake Okeechobee is going to hold all the water that runs back from the 20-Mile Bend. Last year the water simply broke all records by running uphill for 20 miles, from 20-Mile Bend to Lake Okeechobee, and under those conditions, we are not getting much drainage, in fact we are not getting any. The canal is just a designated place to dump water. What we are worried about is that one of these falls, and it may be this fall, the lowest dyke, and I'm afraid that is the one next to me, is going to break while we are waiting to build up a fund sufficient to clean out the canals and get some relief. Thus we may find we don't need any relief when we get the money, because just one break at the right time and we are lost, that is in the fall when our plans are all made. That is the time when we are at the mercy of high water, so I was right encouraged about this idea of getting some type of organization.

After listening to this discussion, I don't know just what type of individual it would be that could kind of segregate all this information and formulate a plan, but certainly there must be someone, and I will say that we need that someone. I have heard all this talk about sums up to $2,000,000. With a project of that dimension, it seems to me there should be some way to raise sufficient funds to relieve the pressure.

I have also heard it mentioned that it would be a good idea to start with what we have and develop a plan as we go along and do what we can, mend the weakest part of our system first and then make further improvements. But with the land that is being sold—just in the last two or three years, in our (the Hillsboro) area, there have been upwards of 75,000 acres of land purchased for development, and that isn't an exaggeration, for there is a large percentage of that being developed today, and within the next six weeks there will be other tracts developed, and all of those tracts lie along one canal—the Hillsboro Canal, thus producing an obvious congestion for it already is inadequate. In other words that area has been taken out of the category of unused land, where formerly the water could overflow, and the water from it is being dumped into the canal, and it is going to run somewhere. We have either got to stop development in that area or we've got to relieve the drainage system. I still believe there is wealth enough in that area, that if we just formulate a workable plan, the money with which Jim (Beardsley) can do something will be forthcoming.

A minimum of money spent in the Hillsboro area would not only give a maximum of benefit but would be an excellent demonstration of what can be accomplished by water control. Disposal of surplus water with an adequate supply to maintain a growing level in periods of drought are but a small part of the benefits to be derived from such control. One really important item is the reduction of the frost hazard which makes possible the use of a greater number of important vegetables that are impractical to grow at the present time. With proper water control, new land could be used for grass in a cattle fattening program which would give further diversion of crops and could become an important part of a rotation program.

There is the further advantage of eliminating insect pests that are always a large item of expense. And, nothing I have said so far has anything to do with the main object of water control, which is the preservation of this unique muck deposit, known as the Everglades, for future generations. I feel sure that the farmers of this area stand ready to supply surplus funds for this purpose in direct proportion to the benefits they would receive. Therefore, in my opinion, the funds necessary for this demonstration would in no way be detrimental to the working out of an overall plan for the Everglades as a whole.

I appreciate this opportunity of expressing my views, and thank you.

Chairman Wallis:

Thank you, Mr. Haney.

I am sorry there isn't time to recognize Dr. Bennett and a number of others. The entire United States is fortunate for the interest he has shown in the conservation of our soils. Those of you who will attend the Clewiston session this evening will have the benefit of hearing Dr. Bennett as well as Mr. John H. Baker, Executive Director of the National Audubon Society. At this time, I will turn the meeting back to Mr. H. I. Mossbarger, President of the Society.

BUSINESS MEETING

Chairman Mossbarger:

Thank you Mr. Wallis. Now we have a little business to attend to. I was under the impression that this organization had gone on record in regard to the Everglades National Park, in the form of a resolution. This certainly should have been done some time ago. The Chair would like to entertain a motion to instruct the Resolutions Committee to prepare a resolution recognizing the fine work of the Everglades National Park Association, the Everglades National Park Commission, the National Park Service and the National Audubon Society in the development of the project and offering the support and cooperation of the Society in every way.

The Secretary:

I wonder if I may be permitted to do that. About ten days ago, we received a letter from Mr. Ernest F. Coe, who is the director of the Everglades National

Park Association. He is a member of the Society, and raised the question of recognition by the Society, of the efforts at developing the Everglades National Park. If I may do so, therefore, I'd like to transmit Mr. Coe's message in the form of a motion, for whatever action you may care to take on it, with the idea of having the matter referred to Mr. Therkildson's Resolutions Committee for appropriate action, as we did all of our resolutions in West Palm Beach last year.

CHAIRMAN MOSSBARGER:

You have heard the motion. Is there a second? The motion that Mr. Coe's suggestion be put in the form of a proper resolution by the Resolutions Committee pledging the cooperation of the Society in the development of the Everglades National Park was seconded by Mr. Wallis.

CHAIRMAN MOSSBARGER:

Any remarks? There was no discussion and the motion was passed by unanimous vote.

CHAIRMAN MOSSBARGER:

There is another matter that I would like to bring to your attention. I think you will agree with me when I say the publishing of the papers reported in these meetings is a valuable service to every member who receives a copy of them. This is going to be done in an interim meeting of this nature largely by sustaining memberships since the $1.00 that is required for annual membership dues doesn't anywhere nearly cover this whole expense. We have been fortunate in getting sufficient support in the past, barely to get these publications out, though usually with considerable delay. We would like to get these reports out more promptly but we can only do this through the aid of sustaining memberships. So I wish each and every one of you would give serious thought to this suggestion and do everything you can to bring in memberships of this type. Are there any other resolutions or suggestions?

DR. NELLER:

I think it would be well to write a letter to Mr. Hobson, Principal of the Belle Glade Schools, and the County School Authorities, thanking them for the use of this auditorium today. You know they use this room all through the day for some of their work, and yet they kindly moved out so we could have access to it. I will make a motion that the Secretary write such a letter to Mr. Hobson, thanking him for his fine cooperation.

The motion was seconded and passed unanimously.

MEMBER:

Mr. Chairman, I'd like to have Mr. Herbert Beck recognized. I think he has a word for us.

CHAIRMAN MOSSBARGER:

Mr. Beck, as the Representative of this Section in the State Legislature we are indeed happy to have you with us.

MR. BECK:

Chairman Mossbarger and Members of the Society: On behalf of the Town of Belle Glade, I want to tell you how much we appreciate the fact that the Society saw fit to have this meeting in this section this year. It means a great deal to all of us, and we hope you will have another meeting here in the very near future.

CHAIRMAN MOSSBARGER:

Thank you Mr. Beck—we have enjoyed your hospitality. Is there any further business?

Mr. Wallis:

Mr. Chairman: I was requested by someone who couldn't be here to propose a resolution expressing the appreciation of the Society for the services of Dr. Allison, not only to the Soil and Water Conservation activities, but his service to the entire Everglades area, and I'd like to have the resolutions committee instructed to prepare such a resolution.

Chairman Mossbarger:

I certainly appreciate that, Mr. Wallis, and am glad to entertain such a motion at this time—I think it is very timely. Is there a second?

Dr. Neller:

I second the motion.

Chairman Mossbarger:

You have heard the motion which has been seconded. Is there any discussion? What is your pleasure. The motion was adopted by unaimous vote.

Chairman Mossbarger:

Is there anything else? We have other members of the legislature present for instance there is Mr. Bollinger back there. Representative Bollinger, won't you say a few words?

Mr. Bollinger:

Mr. Chairman: I have listened very attentively to what has been said. It has been a source of great information to me, and I certainly appreciate the interest the people here are taking in water control activities in this section. I am sure I want to be of as much service to them and to you in your work as possible. I am happy to be here this afternoon.

Chairman Mossbarger:

I think Mr. Hill has probably traveled more miles and covered more meetings than any man in the area and by doing so has been a wonderful help to the entire section—stand up, Joe. Mr. Hill stood up and was duly recognized.

Chairman Mossbarger:

Is there anything else? If not, we will adjourn until 8 o'clock at the Clewiston Inn.

Adjournment 5:15 P. M.
Belle Glade, March 17, 1943.

RESOLUTIONS

A Resolution Requesting Everglades Drainage District to Assume Responsibility for the Development of an Over-All Policy and Plan for the Conservation and Development of the Everglades and to Serve as the Central Authority to Coordinate the Activities of All Governmental and Private Agencies in the Execution of Such Plan.

Whereas, for the Everglades area of Florida the continued success and permanency of agriculture, the conservation and best future utilization of the soils and the protection of domestic water supplies and wild life are now threatened with irreparable loss and damage from the present lack of an over-all policy and plan for adequate and proper water control; and

Whereas, the increased rate of development and use of land during recent years affords some measure of the probable future rate of expansion under the stimulus of war and changing world conditions; and

Whereas, present problems will continue and become more difficult of solution if such increase of land use is not afforded the guidance and protection of an over-all policy and plan for the conservation and development of the natural resources of the area; and

Whereas, the debt problem of Everglades Drainage District, which has so completely interfered with the normal functions of the District for the past twelve years, has finally been solved by the untiring perseverance and help of innumerable persons and all interested agencies under the aggressive leadership of Governor Spessard L. Holland; and

Whereas, the Federal Government has evidenced its increased interest in the Everglades within the past twelve years by the expenditure of twenty millions of dollars on a protective levee around the shores of Lake Okeechobee and by the expenditure of some hundreds of thousands of dollars in making a careful and detailed physical survey and analysis of the hydrology, soils and geology of the Everglades area; and

Whereas, all of this work has produced a vast fund of additional information about the area which it is necessary to take into account in any and all plans for the development and use of the area hereafter; and

Whereas, a proper discharge of the responsibilities of all agencies interested in or concerned with the various phases of conservation and development of the natural resources of the Everglades are seriously handicapped by the present lack of an active Central Authority to coordinate their related activities.

Now, Therefore, Be It Resolved, that Everglades Drainage District be requested to assume responsibility for the development of an over-all policy and plan for the future conservation and development of the land and water resources of the Everglades and to serve as the Central Authority to coordinate the activities of all private and governmental agencies in the execution of such plan.

Be It Further Resolved, that Everglades Drainage District arrange a joint meeting with the Trustees of the Internal Improvement Fund and State Officials in Tallahassee to be attended by representatives of all interested agencies to discuss matters of policy and the steps to be taken towards the adoption of a plan and establishment of the District as the required central authority.

Be It Further Resolved, that the Soil and Water Conservation Committee of the Soil Science Society of Florida extend to Everglades Drainage District the offer of all possible assistance and to serve as an advisory committee in any manner that may be desired.

Be It Futher Resolved, that a copy of this resolution be sent immediately to the Honorable Spessard L. Holland, Governor of Florida, and to each member of his Cabinet and to the Chairman and to each member of the Board of Commissioners of Everglades Drainage District prior to its release to the press and publication in the Fifth Proceedings of the Society.

W. F. Therkildson, Chairman
Resolutions Committee
Soil Science Society of Florida

Belle Glade, Florida
March 17, 1943

A Resolution Recommending the Establishment and Early Development of the Everglades National Park in Southern Florida.

WHEREAS, the Congress of the United States has passed and the President has signed a bill authorizing the Everglades National Park; and

WHEREAS, this park will be distinctive as to climate, flora, fauna and many other physical aspects as compared with other National Parks; and

WHEREAS, the establishment of the Everglades National Park will assure, for all time, protection and preservation of tropical species of wildlife indigenous to the area and those characteristic of the Southeastern United States from the danger of extinction; and

WHEREAS, the water requirements of this great section of South Florida have an indisputably important relationship to those of the Central and Upper Everglades from a number of standpoints; and

WHEREAS, the officials of the Everglades National Park Commission, of the Everglades National Park Association, of the National Park Service, and of the National Audubon Society have labored long and zealously in developing and maintaining public interest in the park project and are fully cognizant of the important place the Everglades National Park will occupy in an overall project for soil and water conservation in South Florida.

NOW, THEREFORE, BE IT RESOLVED, that the Soil Science Society of Florida go on record as unconditionally recommending the establishment and early development of the Everglades National Park as a natural and highly important unit of the Kissimmee Okeechobee-Everglades system for the reclamation and conservation of the soils and waters of this great area and the protection of its abundant wild life; and

BE IT FURTHER RESOLVED, that this resolution be spread upon the minutes of the Society and a copy thereof be transmitted by the Secretary to the Honorable Franklin Delano Roosevelt, President of the United States; to the Honorable Spessard L. Holland, Governor of the State of Florida; to the Director of the National Park Service, U. S. Department of the Interior; to the Executive Director of the National Association of Audubon Societies, and to the proper officials of the Everglades National Park Association and of the Everglades National Park Commission, Miami, Florida.

W. F. THERKILDSON, Chairman
Resolutions Committee
Soil Science Society of Florida

Belle Glade, Florida
March 17, 1943

A Resolution Commending Dr. R. V. Allison for his work with and for the Soil Science Society of Florida and for the Everglades Conservation Project that it is Sponsoring.

Whereas, the Society did at its interim meeting in Belle Glade on March 17, 1943, unanimously direct the Resolutions Committee to prepare a resolution commending Dr. R. V. Allison. Secretary-Treasurer of the Society; and

Whereas, Dr. Allison originated the idea of creating the Soil Science Society of Florida and was its first President, and

Whereas, the Society is indebted to him for its successful initiation and subsequent functioning as a helpful agency in correlating the activities of those interested in soils as related to the agriculture of the State with the activities and findings of the technical soil and agricultural workers in Florida, and

Whereas, the Society has through Dr. Allison's research and investigational achievements been instrumental in focussing attention on the important problem of the Soil and Water Conservation of the Everglades, and

Whereas, he has been instrumental in having the Everglades problem actively investigated and participated in by various cooperating agencies such as the Soil Conservation Service, the State and Federal Geological Departments, the Everglades Drainage District, the Everglades Fire Control Board, the Florida Agricultural Experiment Station, the National Park Service, the Okeechobee Flood Control Board. Municipal and County Organizations in South Florida as well as various corporations and persons, and

Whereas, these agencies and persons are obtaining and correlating a large amount of information about the Everglades and about the necessity for better soil and water conservation in that valuable area, and

Whereas, the great and urgent need for the development of certain conservation measures is becoming realized as necessary by land owners in the Everglades and by State and Federal authorities.

Now, Therefore, Be It Resolved, that Dr. R. V. Allison be and is hereby highly commended for his valuable and untiring aid and leadership in establishing the Society and in the sponsorship of the Soil and Water Conservation Program of the Everglades.

Be It Further Resolved, that this resolution be spread upon the minutes of the Society and that a copy thereof be transmitted to Dr. Allison. Secretary-Treasurer of the Society by the Chairman of the Resolutions Committee.

W. F. Therkildson, Chairman
Resolutions Committee
Soil Science Society of Florida

Belle Glade, Florida
March 17, 1943

APPENDIX

EVERGLADES INSPECTION TRIP
THURSDAY MORNING — MARCH 18, 1943

J. E. Beardsley,[1] in Charge

Following an evening meeting with the Kiwanians in Clewiston and an extemporaneous speech by Mr. John H. Baker, Executive Director of the National Audubon Society,[2] on the preservation of wild life in the Everglades, accompanying the showing of a tremendously interesting color film on the same subject, a group of approximately forty left Clewiston about 10:00 A. M. on the above date for a critical tour of the upper, central and lower Glades along Highway No. 26 and 26-A to study conservation conditions and requirements.[3] The location of the various stops that are briefly discussed below are clearly indicated on the map of Figure 1 which accompanies this review of the trip, most of the text of which was placed in the hands of each member of the group in mimeographed form at the time.

The notes and measurements prepared for consultation at the various stops, supplemented by photos taken in the course of the trip follow:

Stop 1. Everglades Soils Do Burn. Along Highway No. 25, western side Palm Beach County near Hendry County line, note the reddish surface ash that remains, indicative of the high iron content of the original soil. Okeechobee muck at this location will average 50-60 percent ash, while typical Everglades (sawgrass) peat contains only 10-12 percent. Some of the burned areas in this location are several years old; some quite fresh.

Further than this, the picture reproduced as Figure 2[4] below shows the "remains" of a peat dike a few miles south of this location that originally had a height of 10-12 feet; at the time the picture was taken it had burned not merely to the ground surface but *into* the soil to a depth of 12-18 inches—an important aspect of fire control in relation to water control in the Everglades.

Stop 2. The Okeechobee Dike is an indispensable feature in regional water control, especially to the end that it protects inhabited areas around the lake shore from heavy storm waters at such time as they may develop on the lake and also makes feasible the use of the lake as a WATER STORAGE RESERVOIR, which is exceedingly important to the water economy of the whole region.

This dike, including the independent Kissimmee River—Taylor Creek sector, has a total length of 83.4 miles and was constructed under the supervision of the U. S. Engineer Office during the period 1931-1937. The total cost to date, including waterway features and maintenance, has been $23,000,000. The channel produced by its construction between the St. Lucie Canal on the east and Moore Haven on the west thus becomes an important part of an improved waterway totaling 135

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[1] Manager, Board of Commissioners, Everglades Drainage District, Clewiston. (See also Proceedings, Vol. IV-A, p. 104, 1942.)

[2] See page 11 of this Proceedings for the text of Mr. Baker's speech.

[3] Dr. H. H. Bennett, Chief, Soil Conservation Service, U. S. Department of Agriculture also spoke at some length at the evening meeting in Clewiston of his impressions of the Soil and Water Conservation problem in the Everglades as well as elsewhere in the Country and in the Hemisphere. Unfortunately a transcript was not taken of these evening discussions and Dr. Bennett's speech has not otherwise been made available for the record.

[4] See also Proceedings Volume IV-A, Soil Science Society of Florida, p. 39, 1942.

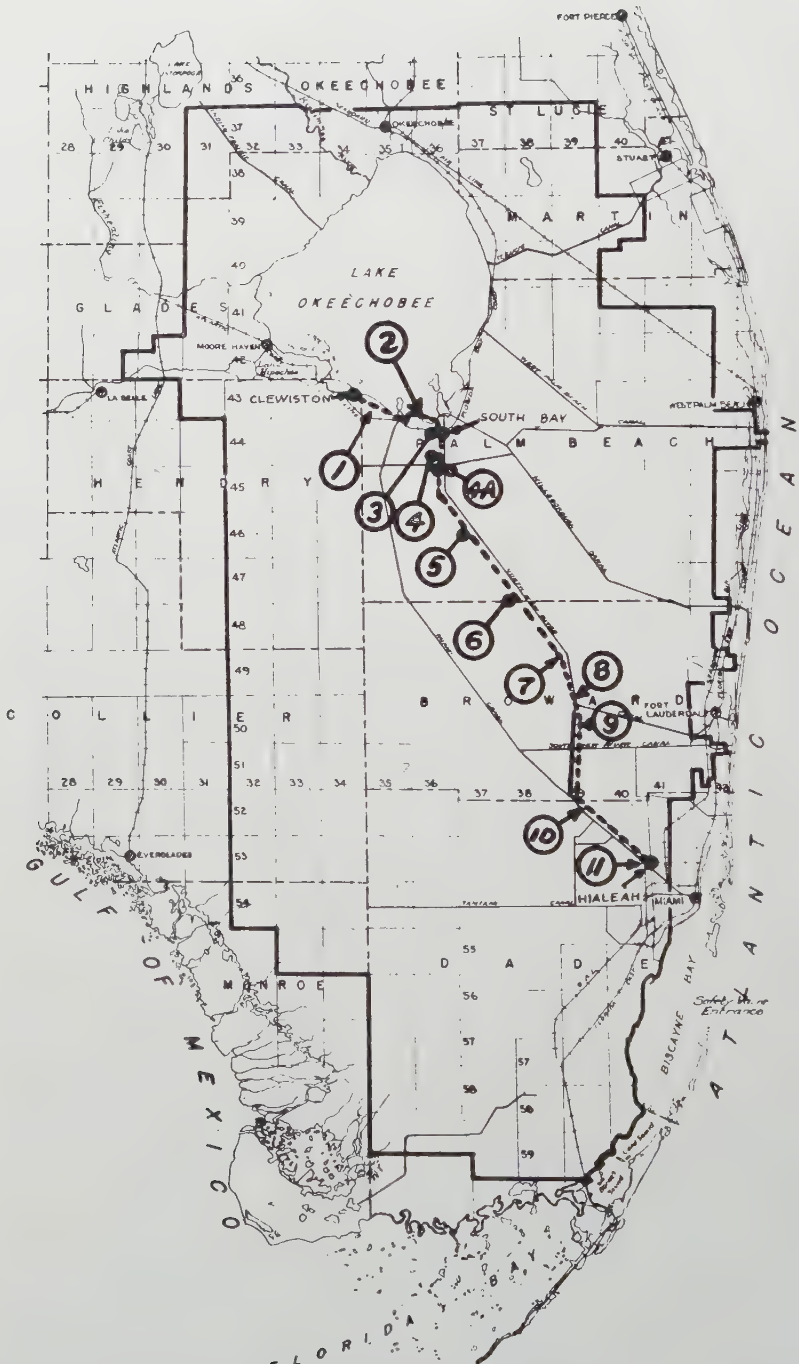

Figure 1.—Map of the Everglades Drainage District showing route of inspection trip and particular stops for which preparations in advance had been made in most instances.

miles in length with a 7-foot clearance at a minimum lake level of 14.0 feet. At an estimated cost of $250,000, this clearance readily could be increased to 8.0 feet.

The dike inspection will continue to the turn-around at the hurricane gate on the Hillsboro. At this point facilities for lake gauging and climatic observations and records can be studied.

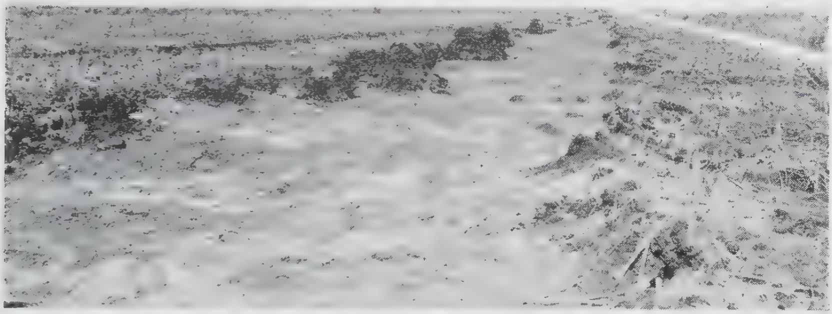

Figure 2.—"Remains" of a 10-foot dike constructed of peat. The entire structure has burned to a depth of 1 to 1½ feet beneath the original ground surface.

Stop 3. A profile of *Okeechobee muck* at the west edge of South Bay exposed to the underlying rock. Here the heavy, plastic topsoil (a true muck) extends to a depth of about 30 inches. The recurrence of this material below a thin layer of brown fibrous peat should be noted. Below the second plastic layer the subsoil is

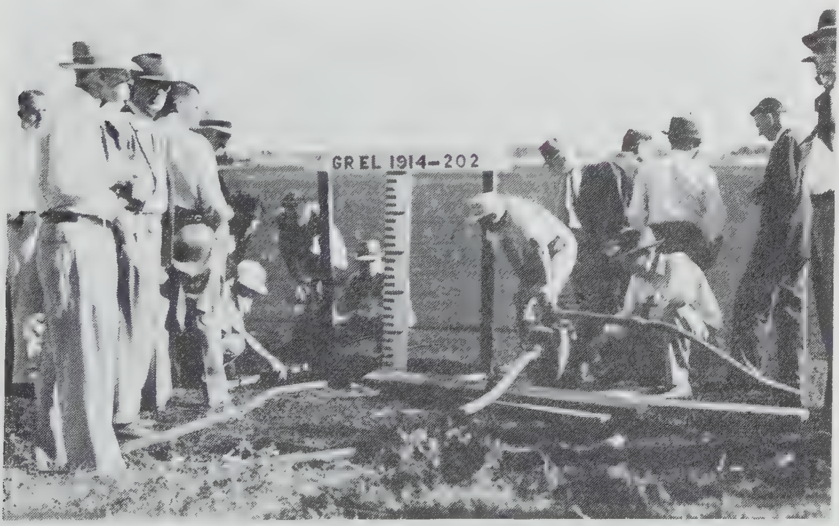

Figure 3.—Inspecting soil character and amount of subsidence at Stop 3 within the townsite of South Bay on the heavy, plastic Okeechobee Muck while the excavation is being pumped. The ground elevation, as of 1914, is shown by the crossbar.

made up largely of brown, fibrous sawgrass peat all the way to the rock floor upon which it rests. (See Figure 3.)

Original depth of soil (1914)	12.6 feet
Present depth of soil (1943)	7.8 feet
Total loss by subsidence	4.8 feet

Stop 4. An exposed profile of *Okeelanta peaty muck* about three miles south of South Bay. Note the topsoil to a depth of 10 inches is a well decomposed peat with a six-inch layer of plastic muck at this point followed by essentially raw, sawgrass peat all the way to the rock beneath. The subsidence figures at this point are found to be as follows:

Original depth of soil (1914)	11.0 feet
Present depth of soil (1943)	5.8 feet
Total loss by subsidence	5.2 feet

Figure 4.—District Manager Beardsley lecturing to the group at Stop 4 and calling attention to the even greater subsidence to be observed at Stop 4A nearer the intersection of the Bolles Canal with the North New River Canal where conditions on both sides of the latter canal were examined.

Stop 4A. East and west side of the North New River Canal at its intersection with the Bolles Canal provides an opportunity to examine an early benchmark set by the U. S. Department of Agriculture in 1916 (Fig. 5), extensive fires that were burning in open fields at the time (Fig. 6) and a temporary benchmark (Fig. 7) that had been set on the west side of the North New River Canal about 600 feet from the highway and ¼ mile north of the Bolles Canal where a total subsidence of six feet is indicated since 1914.

Stop 5. An exposed profile of *Everglades peat* at "Dike B" 16½ miles south of South Bay. Sawgrass peat all the way to the underlying rock with only a faint trace of a plastic layer observed at a depth of 2 feet.

Original depth of soil (1914)	9.0 feet
Present depth of soil (1943)	5.5 feet
Total loss by subsidence	3.5 feet

These dikes B, C, E, and X with dams in the canal at some points, have been constructed by the Soil Conservation Service in cooperation with the Everglades Fire Control Board with the permission of the Board of Commissioners of the Everglades Drainage District for the purpose of holding water on unused and undeveloped sections of the Everglades with a view of fire control as well as soil conservation against natural oxidation.

Stop 6. Everglades peat at the Fire Control Station in the central Glades (Palm Beach-Broward County line), 26½ miles south of South Bay at "Dike C" in the North New River Canal.

Original depth of soil (1914)	4 to 4.5 feet
Present depth of soil (1943)	2.5 to 3 feet
Total loss by subsidence	1.5 feet

Figure 5.—Two views of a permanent benchmark set in 1916 by workers in what was then the Division of Drainage Investigations of the Bureau of Public Roads, U. S. Department of Agriculture, on the east side of the North New River Canal and the south side of the Bolles Canal, that on the right indicating a total subsidence of about 5.8 feet since 1914 according to the best information available on the original elevation of the land. The original depth of the soil to rock was about 11.6 feet at this point; the present depth is about 5.8 feet. The land around this old benchmark has had only gravity drainage. The photo on the left was taken in 1932 when there remained a soil depth of about 6.8 feet; that on the right was taken in March, 1943, only a few days after the inspection.

Though the average depth of soil off the property where it has not been cultivated and packed is 3 feet, 6 inches, such a soil depth in this location, lying over moderately porous limerock as it does, cannot be regarded as agricultural.

Stop 7. Dike and Dam "E" 35 miles south of South Bay at "26-Mile Bend". This dam is designed to back water through the adjacent culvert under Highway 26 into the open glades to the west and south via the borrow pit of Highway 26A.

Figure 6.—Above: Extensive fires burning in the plowed fields in and adjacent to which the benchmark shown in Figure 5 is located at the time of the inspection on March 18th when the water table in the soil stood at about 4 feet below the surface of the land—at least 2 feet too low. Below: An aged landowner is questioned by members of the group regarding the fight she had made during the past few days in protecting her land and her home (background) against the fires with which she was at times practically surrounded, her only means being the sprinkling cans which she holds in her hands. According to her account she had on some occasions to keep watch and work all day and all night.

Figure 7.—Temporary benchmark without excavation about 1/4 mile north of Bolles Canal and 600 feet west of the North New River Canal shows a surface subsidence of nearly six feet since 1914.

Figure 8.—Dam and service bridge across the North New River Canal at "26-Mile Bend" (Dike E) showing about a four-foot head that is illustrative of the only way that water can be held on the open Glades in the face of the presently over-drained conditions which have taken such a toll of land and water resources in this section in the past. (See also Stop 7.)

It is very definitely affecting water table conditions as far north as the fire tower at location 6. "Dike E" extends only a short distance to the east at this point. Head of water against the dam at this time was observed to be about 4 feet. Peat depth at this point from 12 to 15 inches, indicating no agricultural outlook, whatsoever, except for use as an overflow or permanent water reserve area.

STOP 8. EVIDENCE OF A FAILURE. Six miles south of Dike "E" at "Twenty-mile Bend" is to be found the results of an effort at farming this land. Total

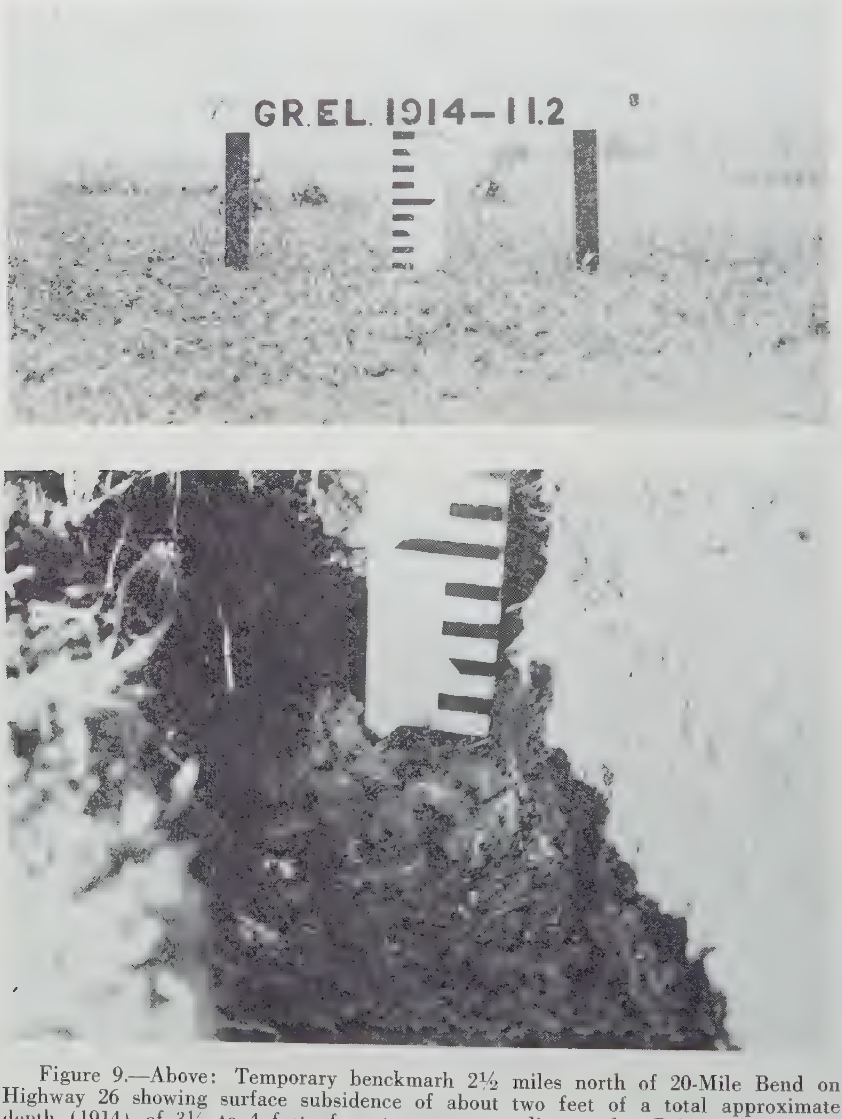

Figure 9.—Above: Temporary benckmarh 2½ miles north of 20-Mile Bend on Highway 26 showing surface subsidence of about two feet of a total approximate depth (1914) of 3½ to 4 feet of peat over porous lime rock. Below: Measuring stick standing on underlying rock, same location as above, in a shallow excavation showing about 1½ feet of loose, fibrous peat remaining at profile referred to under Stop No. 8. Elsewhere in the immediate locality 2 to 2½ feet of peat over the rock could be found.

holding, 43,000 acres; drained and fenced area, about one section. Fences, stock chutes, pump, and canals are in evidence. Continuous pumping under the conditions of a high water table with such facilities as were available scarcely ever reduced the level of the water on the land more than 0.1 foot due, obviously, to the exceed-

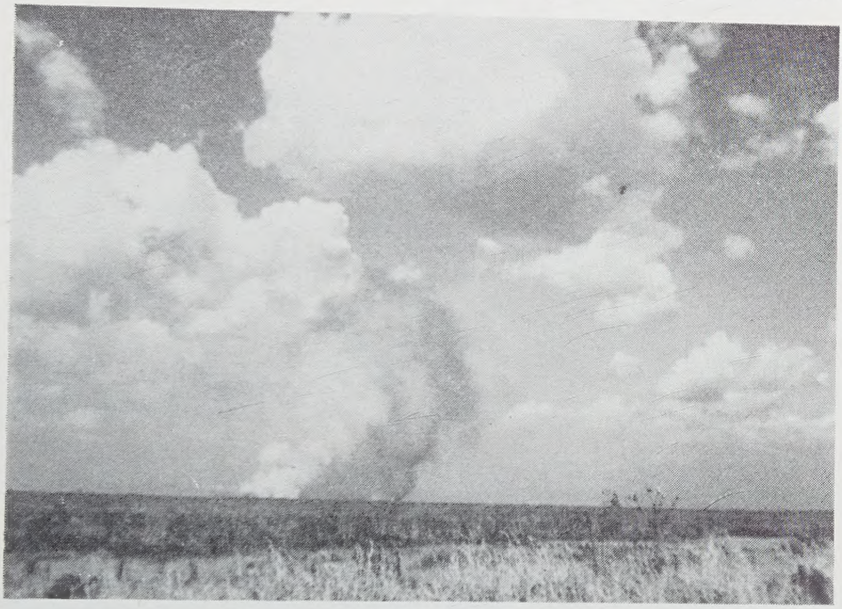

Figure 10.—Above: Fire in the open Glades getting well under way at a point several miles west of Stop No. 8. Below: Closeup of a small section of the burning front of such a fire as shown above taken at another time.

ingly porous character of the underlying rock in this region. The average muck depth in this vicinity is about 3 feet, varying from less than 2 feet to more than 4 feet.

Profile 2¼ miles north of this point (See Figure 9) showed the following average depth and subsidence characteristics:

Original depth of soil (1914)	4.0 feet
Present depth of soil (1943)	2.0 feet
Total loss by subsidence	2.0 feet

Stop 9. The borrow pit of Highway 26-A affords an excellent opportunity between its juncture with 26 and the South New River Canal to observe the variable depth of peat to the underlying marl or oolitic limestone. By glancing along the side of the canal it can be seen to be less than a foot at some points; at other points it has been found to be 4 to 5 feet by numerous soundings. The minimum depth, of course, regulates the agricultural outlook of a soil of this nature where the variation are local and where the soil is underlain by hard rock. In this location, however, the exceptional porosity of the rock (comparable to washed gravel according to geologists) is an even more dominant factor in its relation to water control.

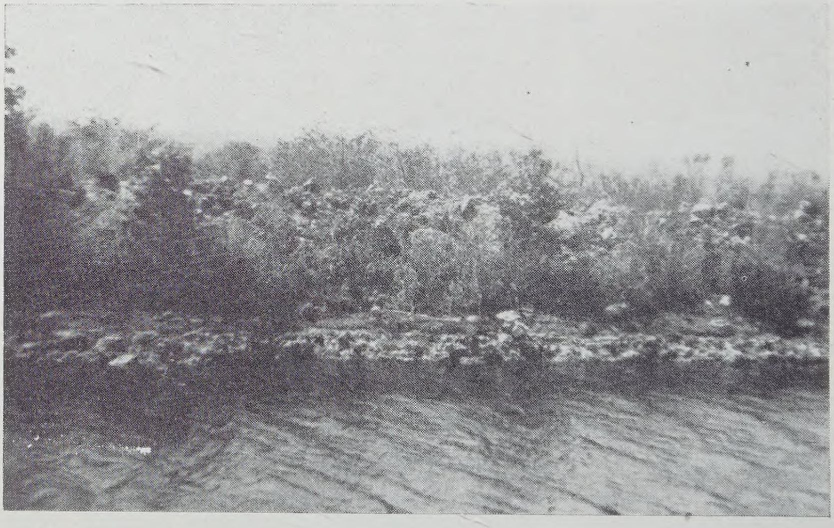

Figure 11.—Looking west across the borrow pit of Highway 26A at Stop No. 9. Note exceeding shallowness of peat soil over the porous lime rock. The hazy background is due to extensive fires under way in this general area at the time of the inspection. Note also that the natural water table is down in the rock and well below the lower surface of the peat, an especially dangerous exposure for a soil of this nature.

Stop 10. Oolitic limerock. The sieve-like structure of the oolitic limerock underlying the soils of extensive areas of the lower Everglades reveals why water control against such a foundation material is so exceedingly difficult and, in fact, usually impossible within the limitations of practical agricultural operations. This condition is quite thoroughly discussed in the present volume by Messrs. Garald G. Parker, Nevin D. Hoy and J. C. Stephens under the general title "Further Studies of Geological relationships affecting soil and water conservation and land use in the Everglades" on pages 33-94.

Stop 11. The Hialeah gauging station of the U. S. Geological Survey, with appropriate rainfall and evaporation equipment, is a typical unit in the highly important surface and ground water studies that are being conducted by this Service throughout the Everglades area. The Canal discharge records at such stations show the amount of water which is removed from the Glades by the large canals. By

Figure 12.—Above: Geologist G. G. Parker (hammer in hand) explains the oolite formation from atop huge boulders of it at Stop 10 that have been thrown out as spoil in excavating Miami Canal and again (below) in Hialeath, following Stop 11, on the pile of spoil thrown out at the 36th Street site of the floating dam designed to prevent salt water encroachment up the Canal. It was at this latter site that the sample was collected for the photo shown by Mr. J. C. Stephens on page 70 of this Proceedings.

proper control dams much of this water could be retained on the peat lands. It is only by the systematic extension and prosecution of these studies that we shall gather adequate information for the intelligent handling and conservation of one of our most important natural resources—WATER.